(NASA-CR-173398) SHUTTLE INTERACTION STUDY EXTENSION Final Review (Rockwell International Corp.) 257 p HC A12/MF A01 CSCL 14B

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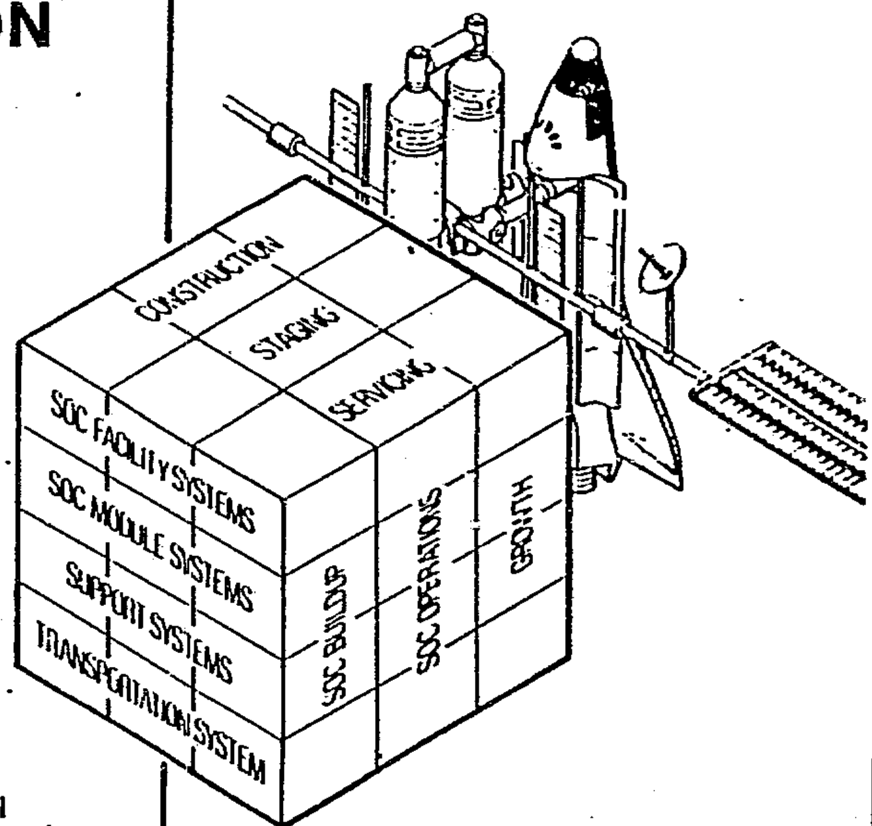
SPACE OPERATIONS CENTER

SHUTTLE INTERACTION STUDY EXTENSION

FINAL REVIEW

NAS9-16153

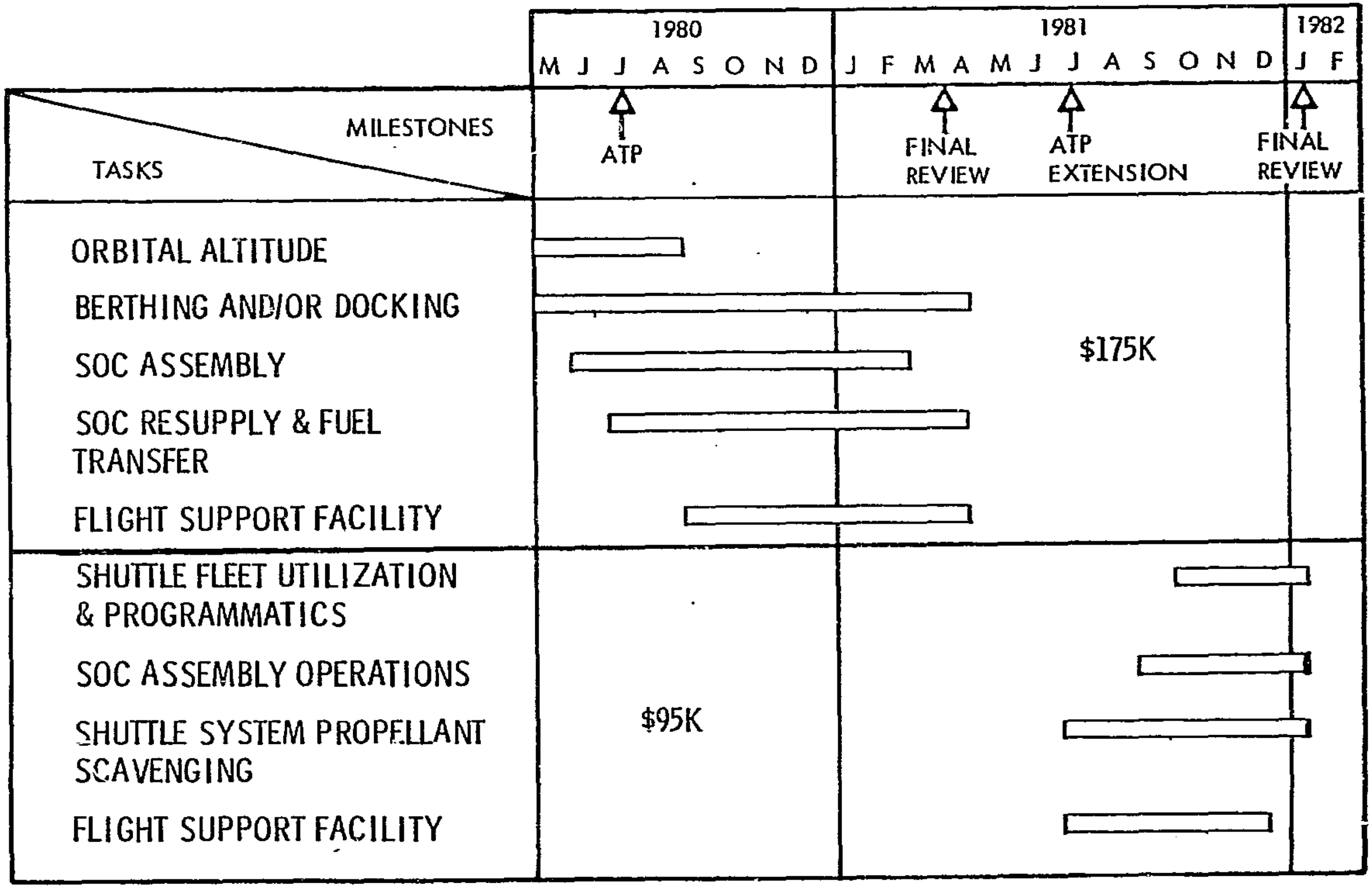


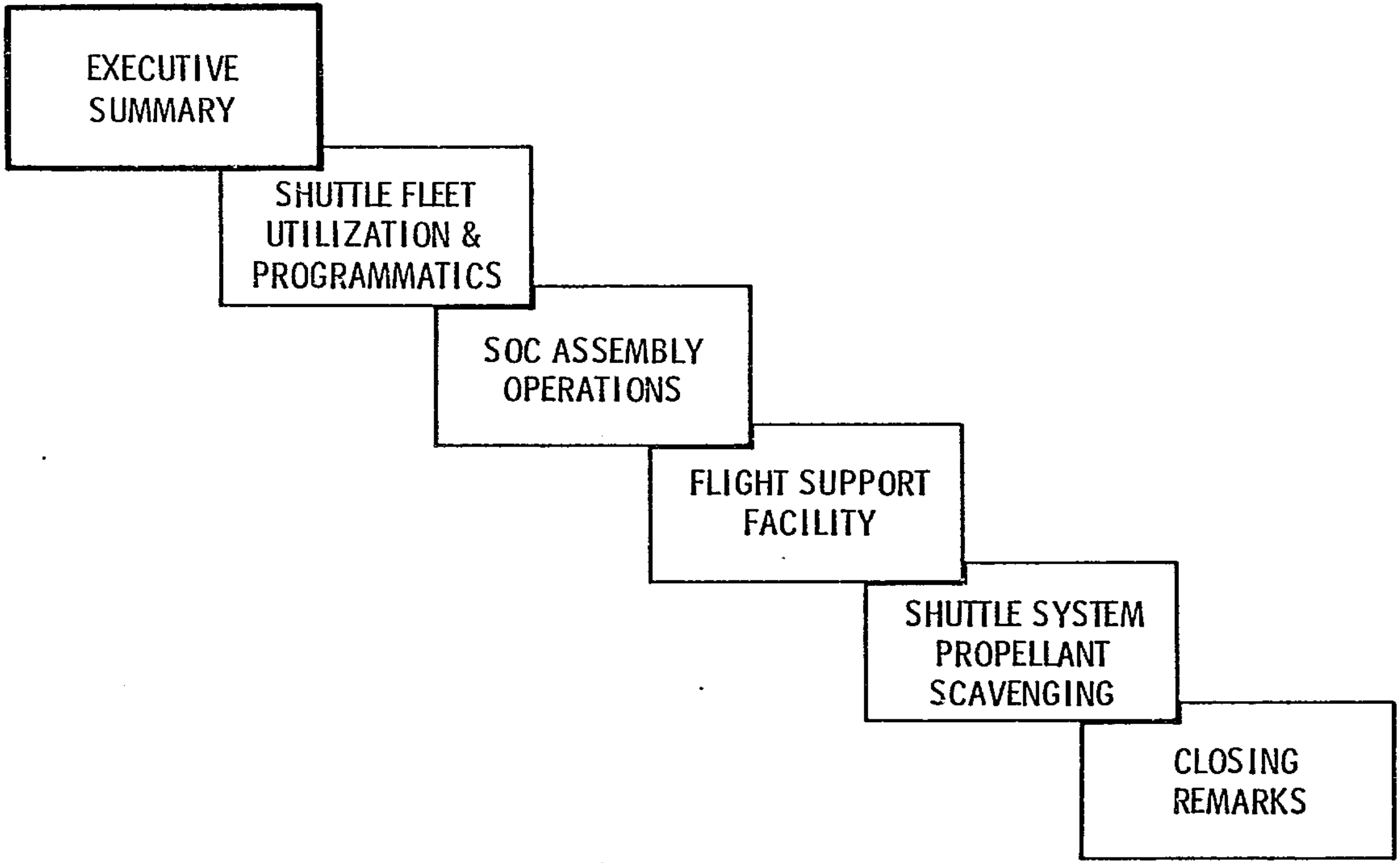
Space Operations/Integration & Satellite Systems Division

Rockwell International

FEBRUARY 1982

SOC -- SHUTTLE INTERACTION STUDY TASKS





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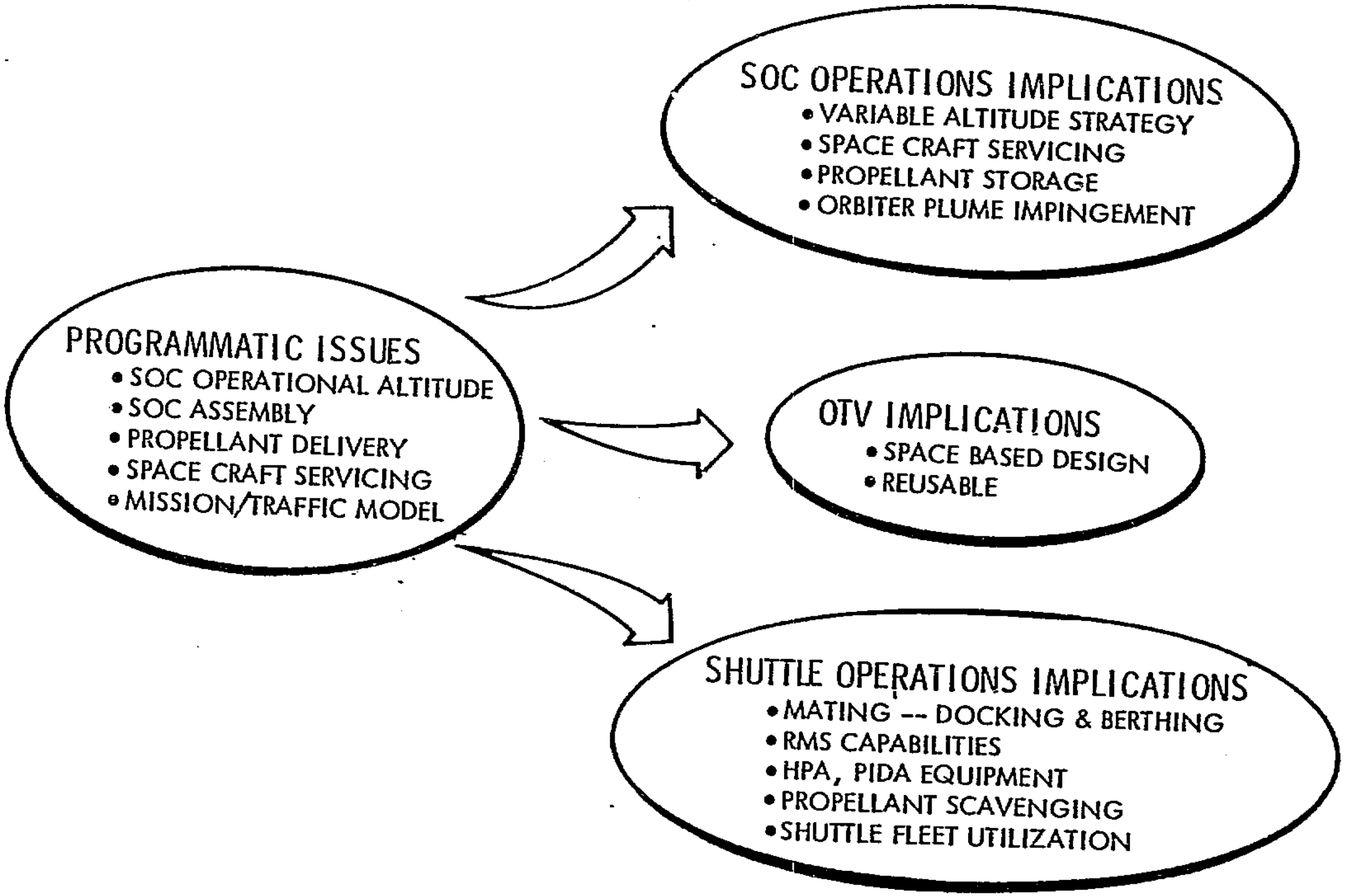
SPACE OPERATIONS CENTER - SHUTTLE INTERACTION STUDY SUMMARY

The nine individual tasks can be grouped into five general areas or programmatic issues as indicated on this chart. The principal implication areas associated with the SOC, Orbiter, and OTV are also shown. The OTV is listed because of its major influence on the overall space program as well as its influence on the SOC.

SPACE OPERATIONS CENTER - SHUTTLE INTERACTION STUDY SUMMARY



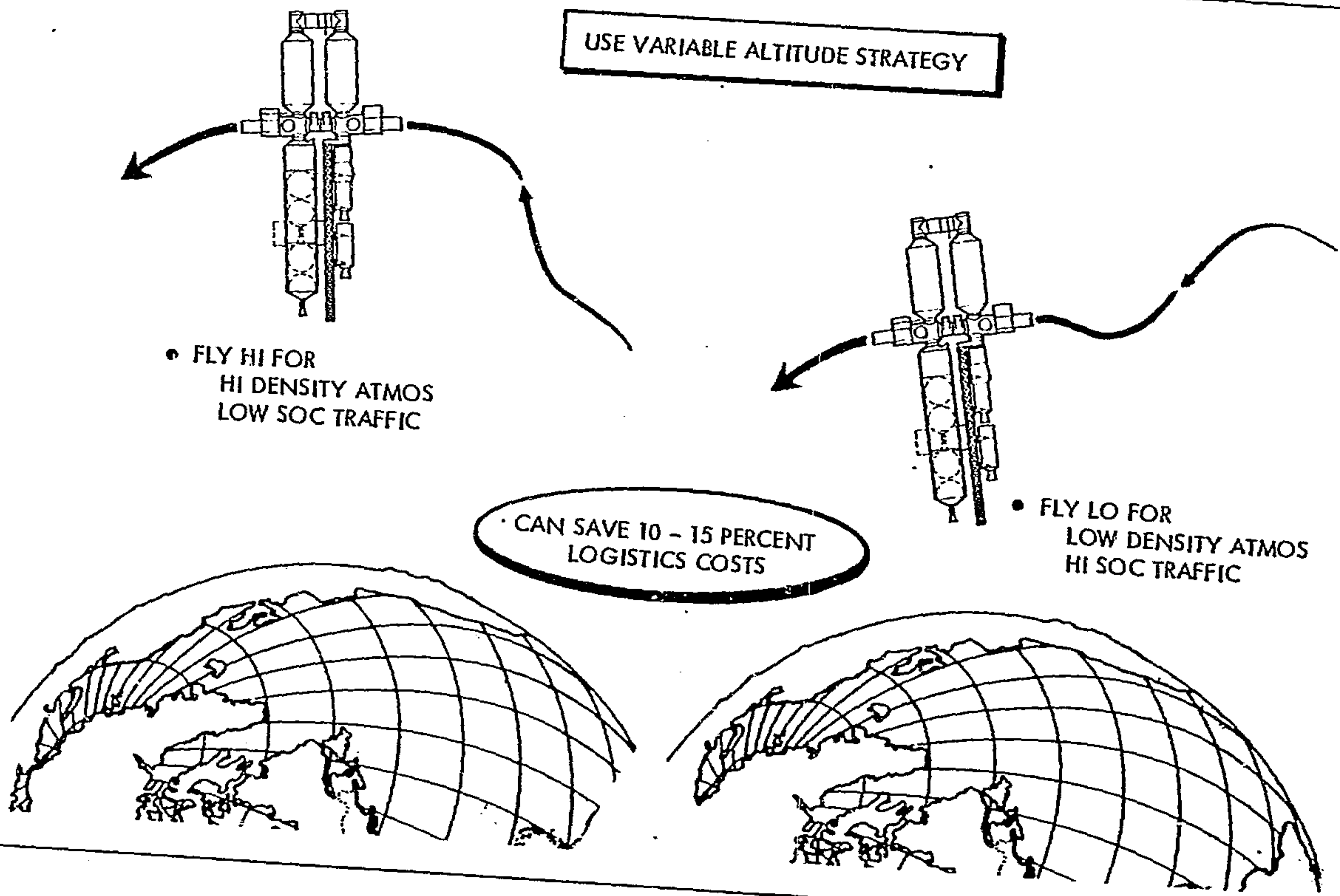
SOC OPERATIONAL ALTITUDE

SOC ORBIT ALTITUDE STRATEGY

The principal object of the SOC Operational Altitude task was to seek out the most effective orbit altitude strategy for the SOC that utilizes the maximum potential of the Space Shuttle and at the same time provides adequate safety and an efficient operating base for SOC.

The variable altitude strategy was recommended as a result of the analysis because it combines safety of operation with logistics delivery efficiency - saves 10% - 15% of the number of shuttle flights as compared to flying a fixed altitude.

SOC ORBIT ALTITUDE STRATEGY

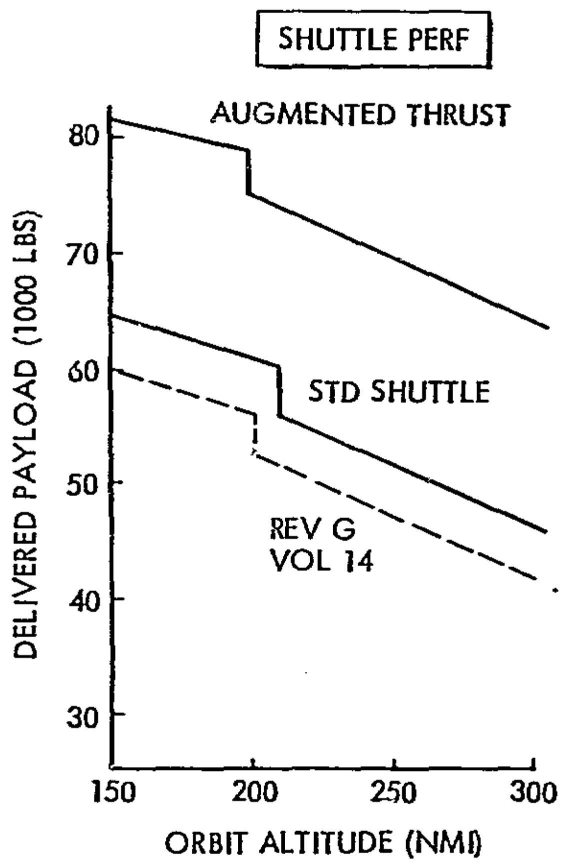


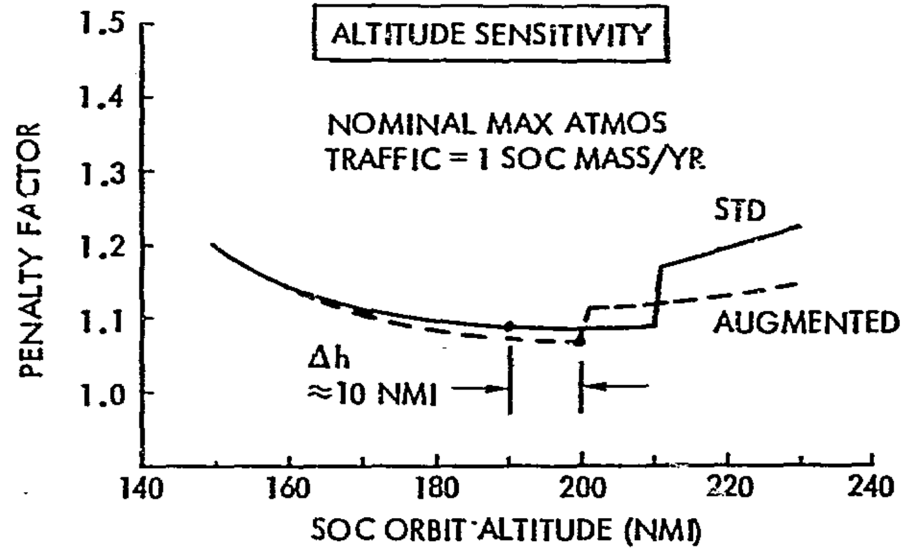
DELIVERY PERFORMANCE COMPARISON

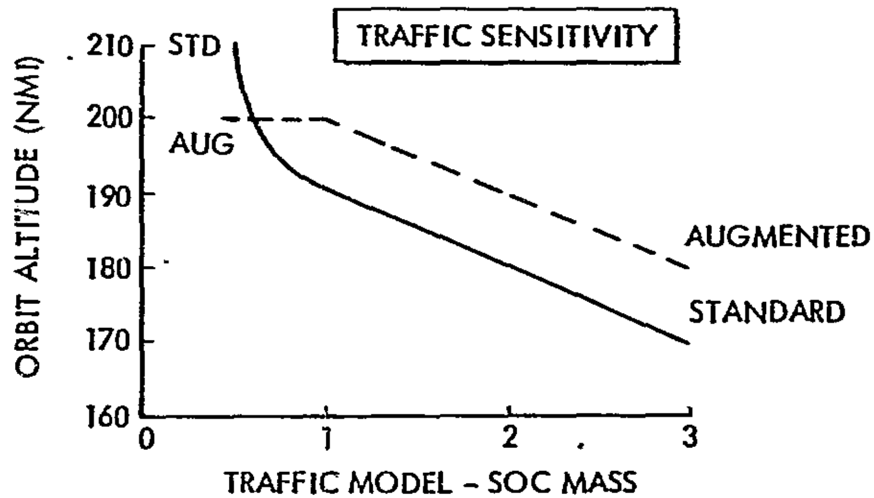
The SOC Operational Altitude analysis also compared operations of the standard shuttle with an augmented shuttle having the capability to delivery 80K pounds of cargo. The analysis showed that the standard shuttle can do the job; it can deliver the SOC modules for initial assembly, and can deliver logistics cargo within 10 nm of the augmented orbiter capability.

DELIVERY PERFORMANCE COMPARISON

STANDARD SHUTTLE CAN DO THE JOB







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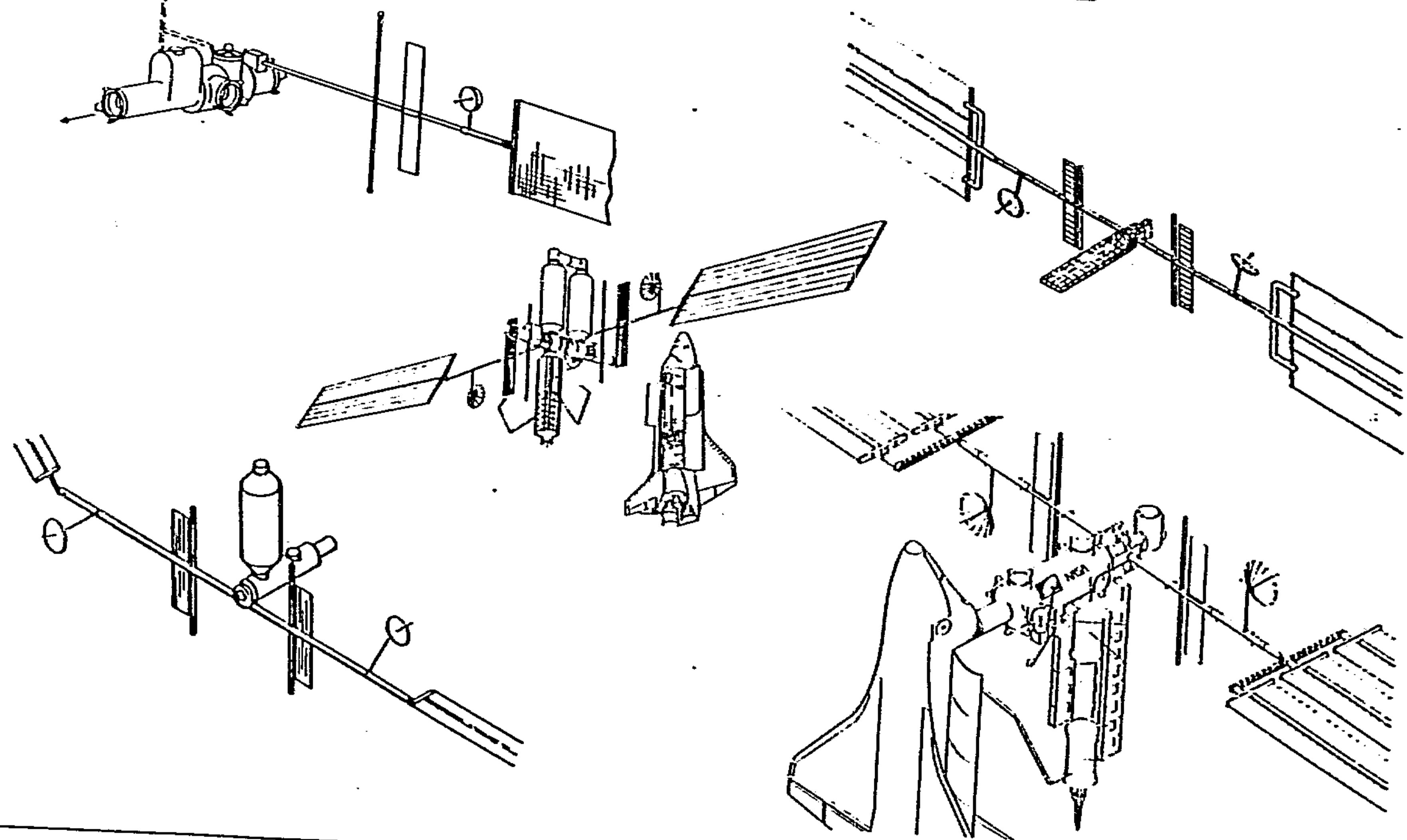
SOC ASSEMBLY

EARLY OPERATIONAL CONCEPTS

The SOC area includes both the SOC assembly operations and the orbiter mating operations.

Many variations of SOC configurations and assembly sequences are possible at this stage of Space Operations Systems Studies. Such candidates are shown here.

ORBITER CAN ASSEMBLE ALL SOC ARRANGEMENTS

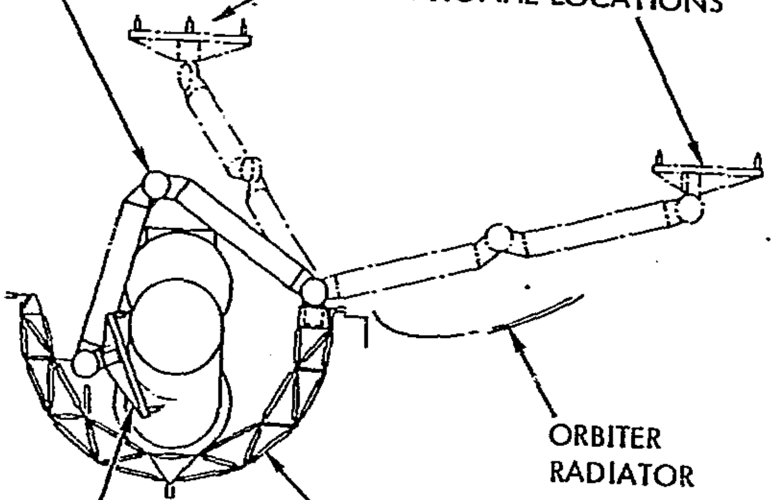


ASSEMBLY AIDS

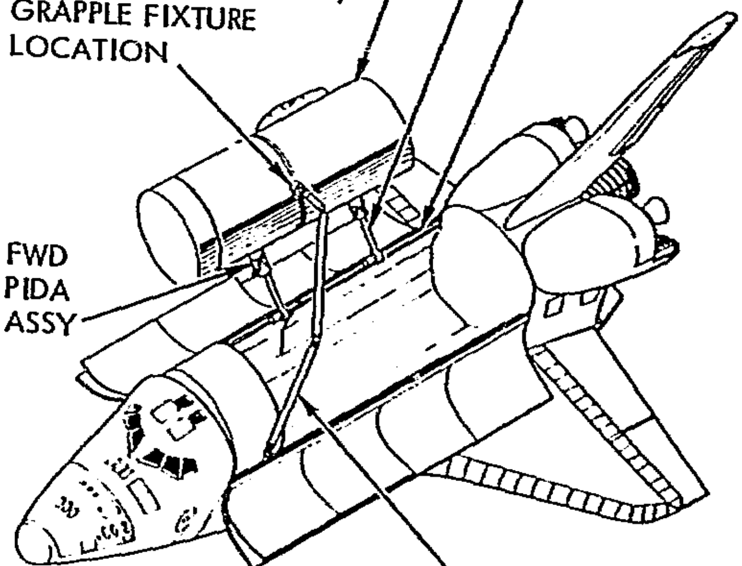
The principal issue of the SOC assembly task was to determine if the Orbiter utilizing the RMS could assemble a SOC. Our analysis indicates that the orbiter has this capability with the aid of the HPA and the PIPA devices.

STANDARD ORBITER EQUIPMENT CAN DO THE JOB

HANDLING & POSITIONING AID



PAYLOAD INSTALLATION & DEPLOYMENT AID



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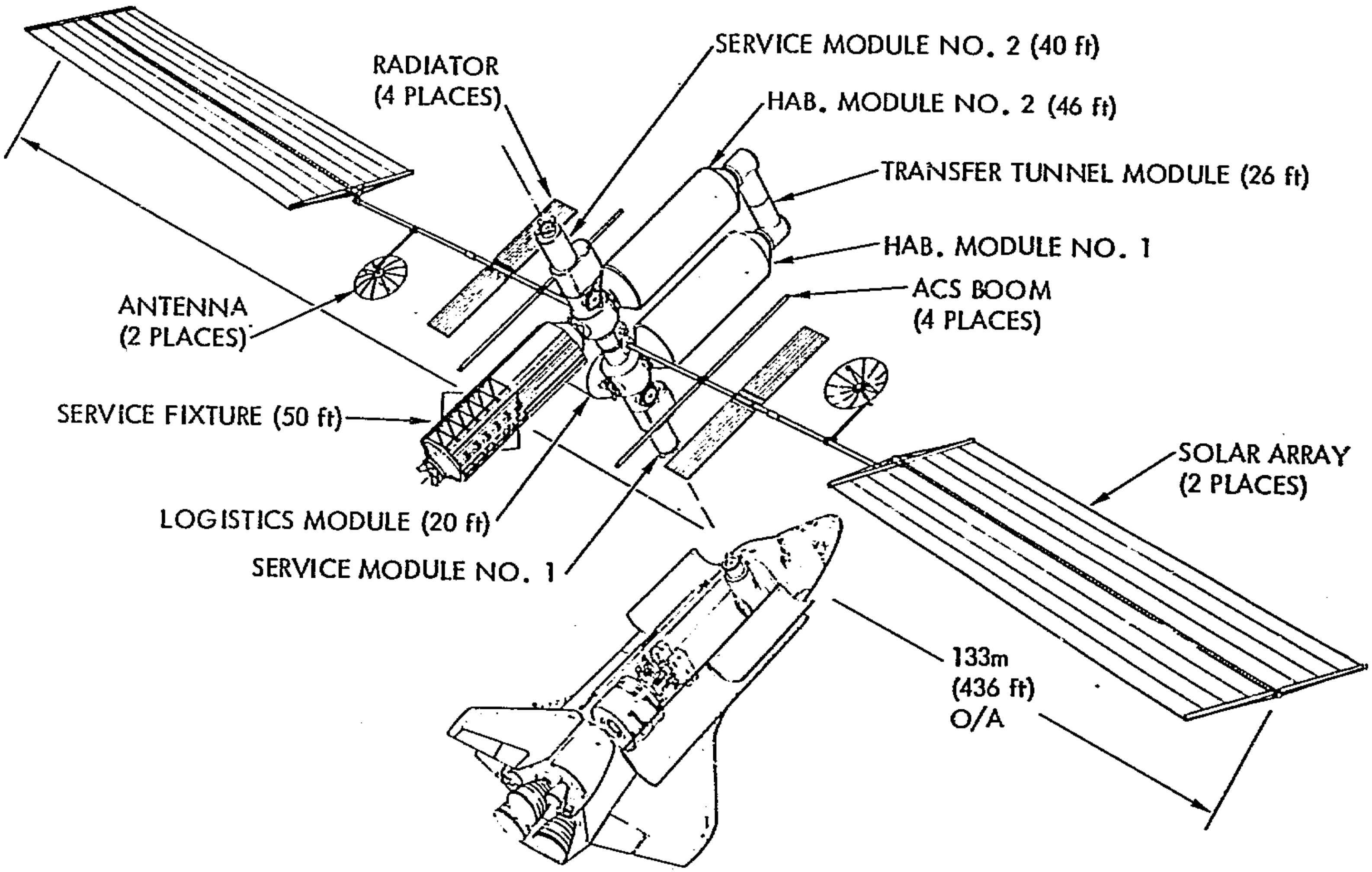
SPACE OPERATIONS CENTER (SOC)
MODIFIED REFERENCE CONFIGURATION



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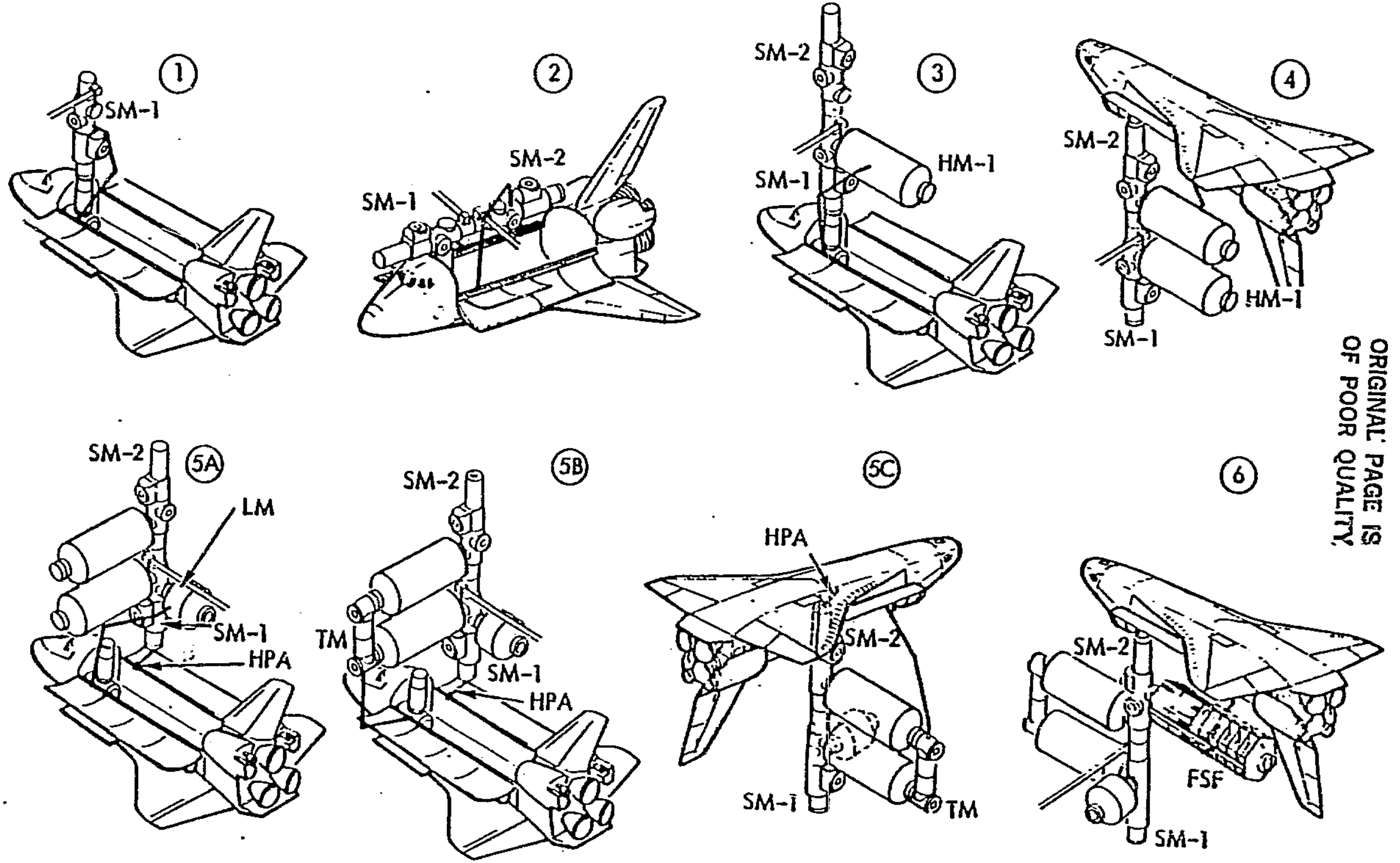
SOC ASSEMBLY - CONCEPT A

The assembly operations of the SOC Modified Reference Configuration, illustrated on the previous chart, are shown here. The assembly sequence and relative positions between the SOC and Orbiter are indicated.

The joint angles of the RMS were verified to be within their operational capability. The tabulation of the joint angles are shown on the following chart.

SOC ASSEMBLY - CONCEPT A



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RMS JOINT ANGLES - SOC ASSEMBLY CONCEPT A

MODULE \ RMS JOINT (MAX LIMIT)	SY (-177.4 TO 177.4)	SP (0.6 TO 142.4)	EP (-0.4 TO -157.6)	WP (-116.4 TO 116.4)	WY (-116.6 TO 116.6)	WR (-442 TO 442)
SM-1 STOWED	-31.51	49.50	-69.39	-46.78	-32.86	-51.53
SM-1 DEPLOYED	-119.14	129.60	-109.42	-42.22	27.33	100.53
SM-2 STOWED	-31.51	49.50	-69.39	-46.78	-37.86 *	-51.53
SM-2 DEPLOYED	-8.73	85.31	-110.91	-41.17	-68.72	114.74
HM-1 STOWED	-34.96	68.48	-92.42	-40.76	-31.44 *	132.19
HM-1 DEPLOYED	-21.49	78.27	-42.47	-79.80	-61.31	139.73
HM-2 STOWED	-34.96	68.48	-92.42	-40.76	-31.44 *	132.19
HM-2 DEPLOYED	-21.49	78.27	-42.47	-79.80	-61.31	139.73
LM STOWED	-49.59	87.77	-118.34	-29.30	-24.36	147.00
LM DEPLOYED	-61.31	75.58	-68.93	-28.61	-26.91	169.66
TM STOWED	-20.27	59.44	-114.29	-21.67	24.36	-75.00
TM DEPLOYED	56.74	94.02	-54.29	112.14	46.31	130.00
FSF STOWED	-33.56	65.64	-88.43 *	-42.70	-32.02 *	131.00
FSF DEPLOYED	-20.72	73.61	-36.52	-82.09	-61.86	138.50

* JOINT ANGLES EXCEEDING DESIRED RANGE (EP>40°; WY<±60°)

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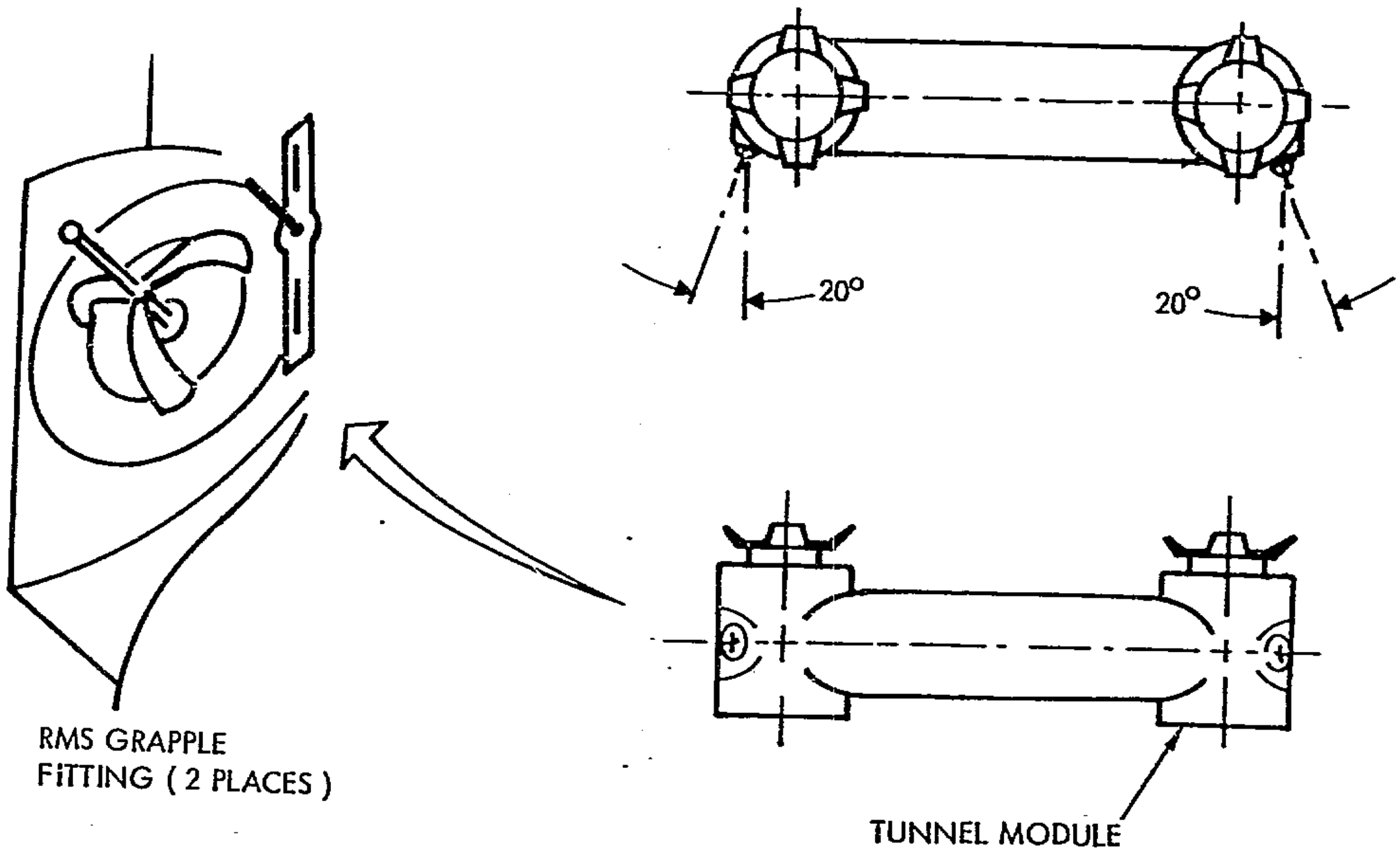
TUNNEL MODULE GRAPPLE LOCATION

The SOC assembly task also justified the location of the grapple fixtures on each module. One example of a unique position for grapple fixtures is shown here for the tunnel module.

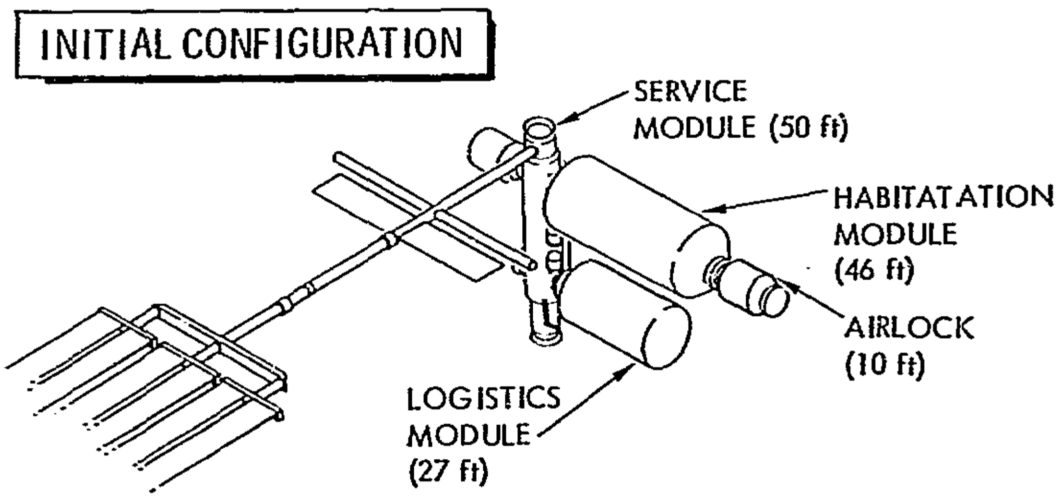
TUNNEL MODULE GRAPPLE LOCATION

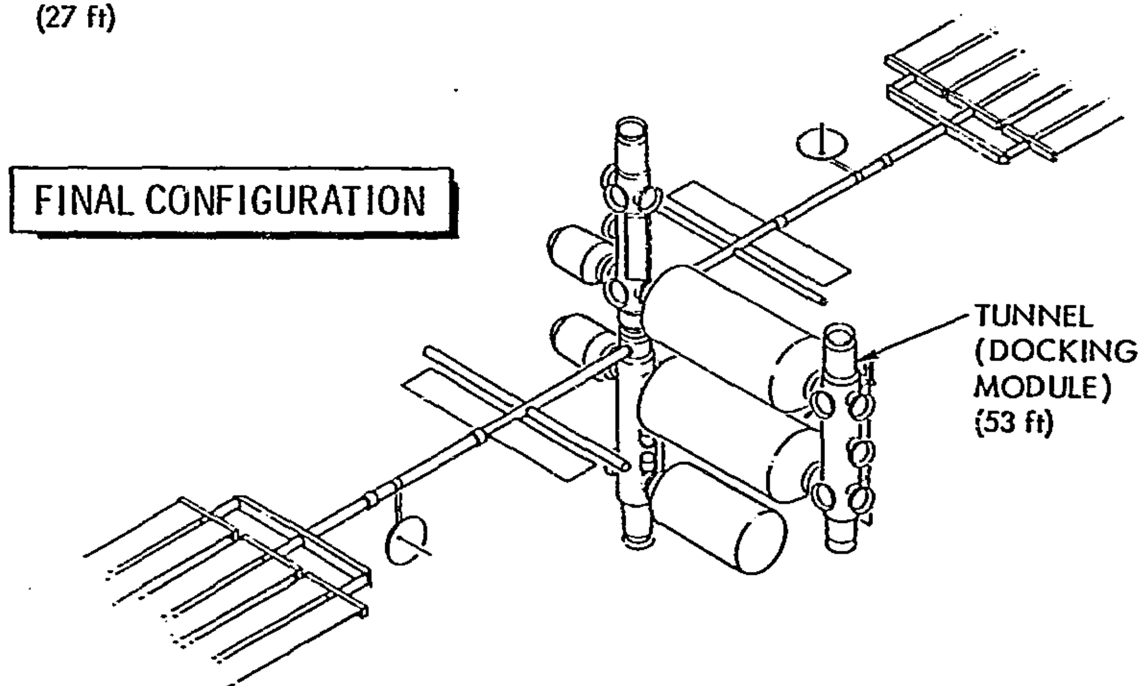


SOC OPERATIONAL CONFIGURATION B

The SOC assembly implications were also examined for the baseline configuration as defined by Boeing in the first phase of their study effort. This concept introduces the incremental build-up sequence. The modules sizes are generally larger than the reference configuration, such as the 50 ft. service module and the 53 ft. tunnel or docking module. We have determined that the orbiter with the RMS aided by the HPA can assemble this configuration.

SOC OPERATIONAL CONFIGURATION B

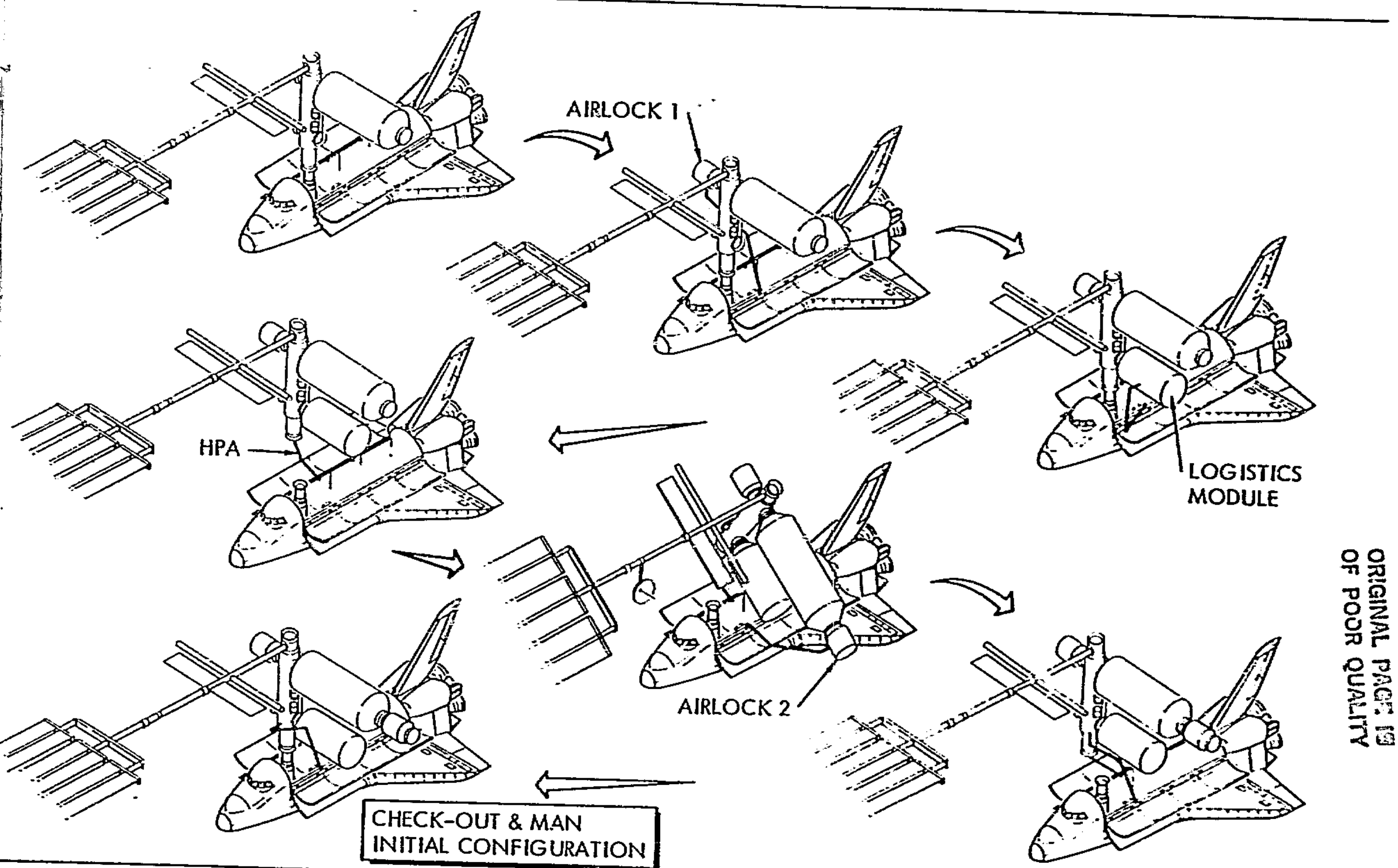




SOC ASSEMBLY - CONCEPT B
FLIGHT 3

The final assembly sequence for the initial configuration is illustrated on this chart. The assembly operations require the use of the HPA in a tilt position to bring the end of the habitat module within reach of the RMS in order to mate the airlock at this position.

SOC ASSEMBLY - CONCEPT B
FLIGHT 3



SOC ASSEMBLY - CONCEPT B
FLIGHT 5

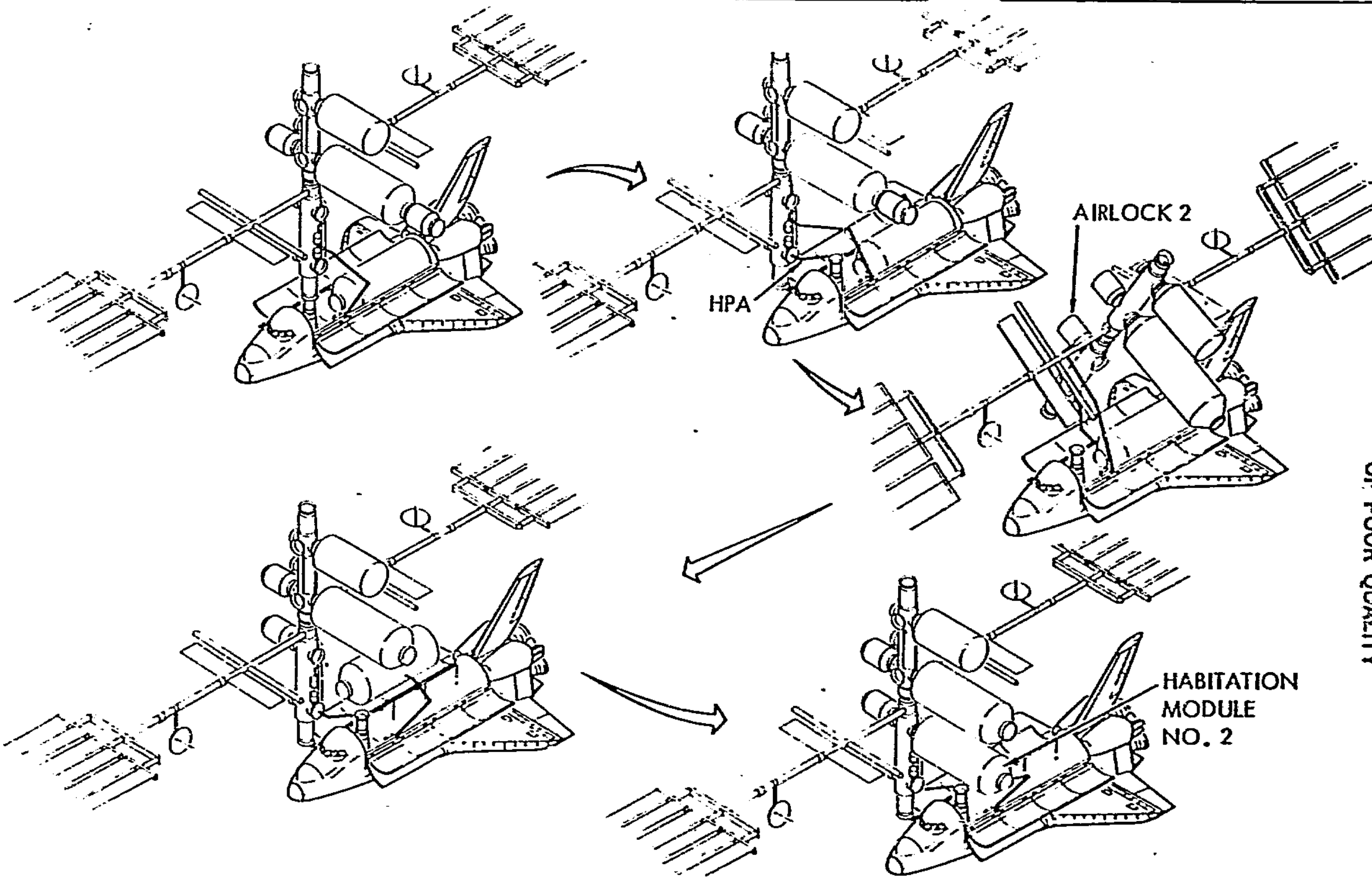
The assembly sequence depicted on this chart illustrates some of the complex operations involved to complete the SOC configuration.

The assembly operations are complicated by the 50 ft. long service modules. The HPA is required more frequently and these operations may impose some unique design requirements on it.

The RMS control software may also be affected because, as shown here, some assembly maneuvers require the repositioning of a nearly full-up SOC from the module to the HPA and back again. These docking maneuvers are not too unlike the orbiter berthing simulations that were performed by SPAR of Canada last year that indicated the requirement for software mods in order to perform these maneuvers.

Many of the orbiter positions required to perform the assembly operations are 90° to the nominal earth pointing operational orientation. Orbiter approach control operations need to be examined in more detail for this maneuver.

SOC ASSEMBLY - CONCEPT B
FLIGHT 5



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RMS JOINT ANGLES, SOC ASSEMBLY—CONCEPT B

RMS JOINT (MAXIMUM LIMIT) / MODULE	SY (-177.4 TO 177.4)		SP (0.6 TO 142.4)		EP (-0.4 TO -157.6)		WP (-116.4 TO 116.4)		WY (-116.6 TO 116.6)		WR (-442 TO 442)	
	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
2A/B (SOC)	-166.17	-137.71	105.46	56.96	-129.75	-93.04	-32.66	8.36	66.27	44.22	0	0
2C/D (HM-1)	-58.55	-97.45	96.10	86.81	-123.75	-103.44	-27.21	-0.77	-19.39	-37.93	0	0
2E/F (SOC)	-166.17	-137.71	105.46	56.96	-129.75	-93.04	-32.66	8.36	66.27	44.22	0	0
3A/B (A/L-1)	-48.29	-88.61	92.06	71.48	-146.58	-47.83	-50.27	48.20	12.82	-45.45	0	0
3C (LM)	-30.22	49.81	59.44	132.57	-78.41	-114.79	-48.49	59.56	-33.36	76.01*	0	0
3E (A/L-2)	-26.02	90.11	71.10	91.71	-120.44	-74.47	-49.48	107.24	17.44	0.06	0	0
3F (SOC)	-113.36	-90.07	116.06	64.27	-85.24	-55.60	-51.89	-28.14	21.95	0.07	0	0
4A/B (SOC	-113.36	-138.56	116.06	70.39	-85.24	-81.64	-51.89	-16.88	21.95	44.97	0	0
4B/C (SM-2)	-35.15	-49.80	64.01	47.42	-100.40	-81.93	-28.21	109.40	-31.35	-12.43	0	0
5A/B (SOC)	-113.36	-112.37	116.06	58.09	-85.24	-91.35	-51.89	12.33	21.95	21.02	0	0
5C (A/L-2)	124.91	-118.01	85.53	43.63	-49.72	-50.64	19.16	3.91	-21.83	72.82*	0	0
5D (HM-2)	-32.10	-132.10	64.21	94.49	-85.45	-130.22	-45.09	111.03	-32.62	12.92	0	0
6A/B (SOC)	-113.36	-113.13	116.06	70.54	-85.24	-59.85	-51.89	-31.73	21.95	21.73	0	0
6C (TM)	-86.16	145.45	72.89	105.06	-107.36	-69.72	-74.36	-3.39	1.28	-50.93	0	0

* JOINT ANGLES EXCEEDING DESIRED RANGE (EP > 40°; WY < ±60°)

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COMPARISON OF SOC ASSEMBLY CONCEPTS

A comparison of the two SOC assembly examples are shown here. The principal areas to note are the number of times the HPA is required and the number of grappling, transfer and berthing operations required for essentially the same number of modules.

COMPARISON OF SOC ASSEMBLY CONCEPTS

		A	B
NO. OF FLIGHTS REQUIRED FOR ASSEMBLY		6	6
NO. OF MODULES		7	8
LENGTH OF MODULES, M (ft)	SERVICE MODULE	12.19 (40)	15.24 (50)
	HABITATION MODULE	14.02 (46)	14.02 (46)
	TUNNEL (DOCKING) MOD.	7.87 (26)	16.15 (53)
FLIGHTS REQUIRING HPA		1	5
SOC PORTS INTERFACING WITH	ORBITER DM	3	3
	HPA	2	4
DOCKING OPERATIONS		6	6
GRAPPLING, TRANSFER & BERTHING OPERATIONS		10	20
DISASSEMBLY OPERATIONS		0	1
SOC PORTS REQUIRING DOCKING INCREMENTS OF	90^0	0	2
	180^0	2	0
DEVIATIONS FROM RMS JOINT ANGLES	DESIRED LIMITS	5	2
	MAX LIMITS	0	C

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ASSEMBLY CONSIDERATIONS

- HPA DESIGN CRITERA
- RMS CONTROL MAY REQUIRE SOFTWARE CHANGES
- ORBITER APPROACH CONTROL

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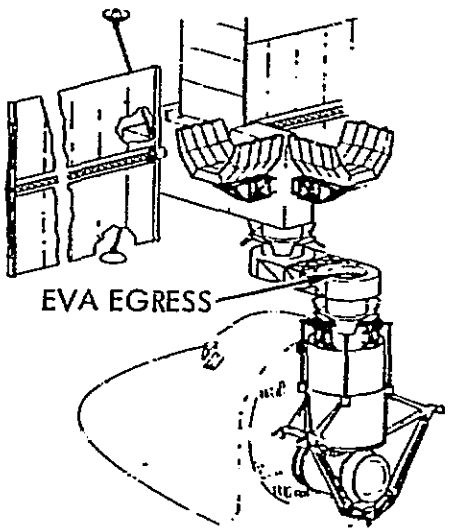
ORBITER MATING

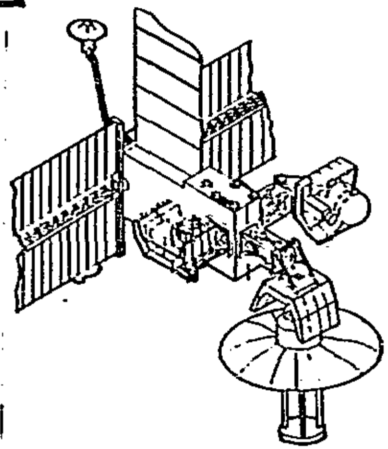
SPACE PROGRAM ELEMENTS REQUIRING MATING

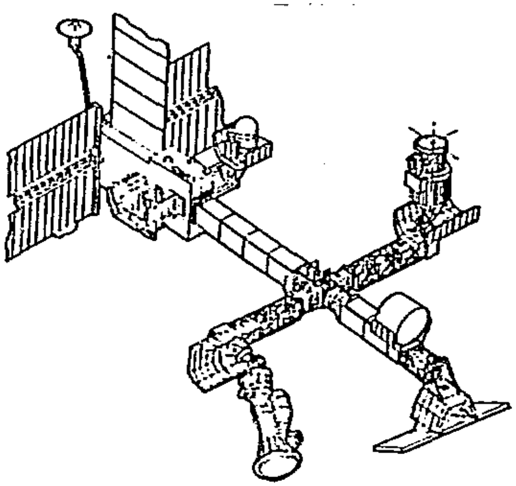
As previously indicated, the orbiter and module mating operations (Berthing/Docking) is also considered in the SOC assembly area analysis. The principal objective was to define a standard mating interface that could be used for other space programs as well as the SOC. Examples of other space programs that require orbiter and module mating are illustrated on this chart.

SPACE PROGRAM ELEMENTS REQUIRING MATING

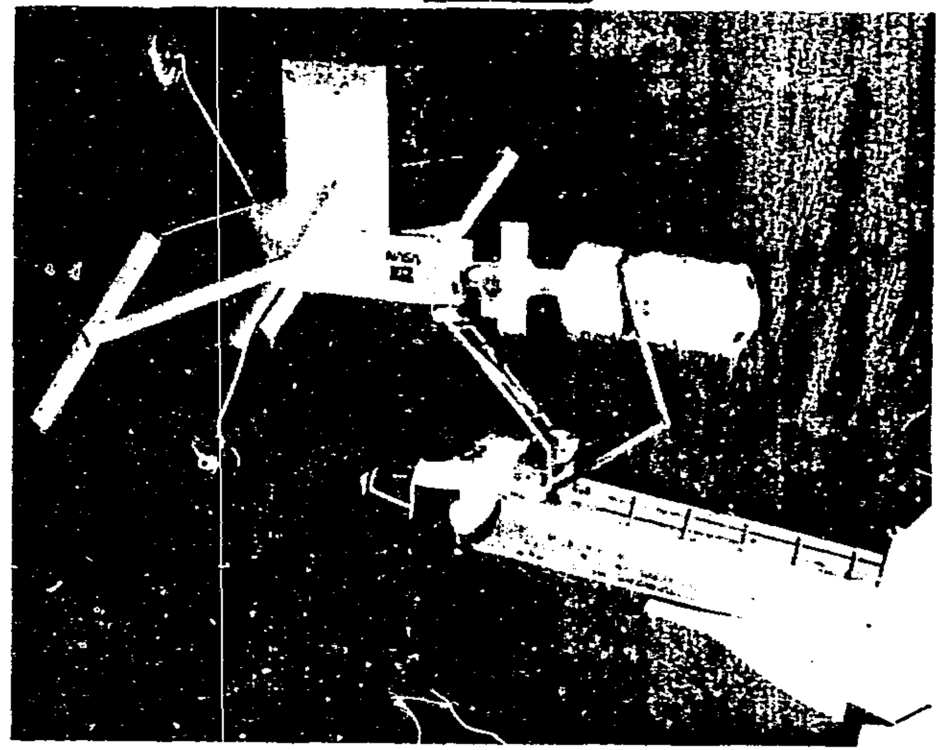
SASP







SAMSP

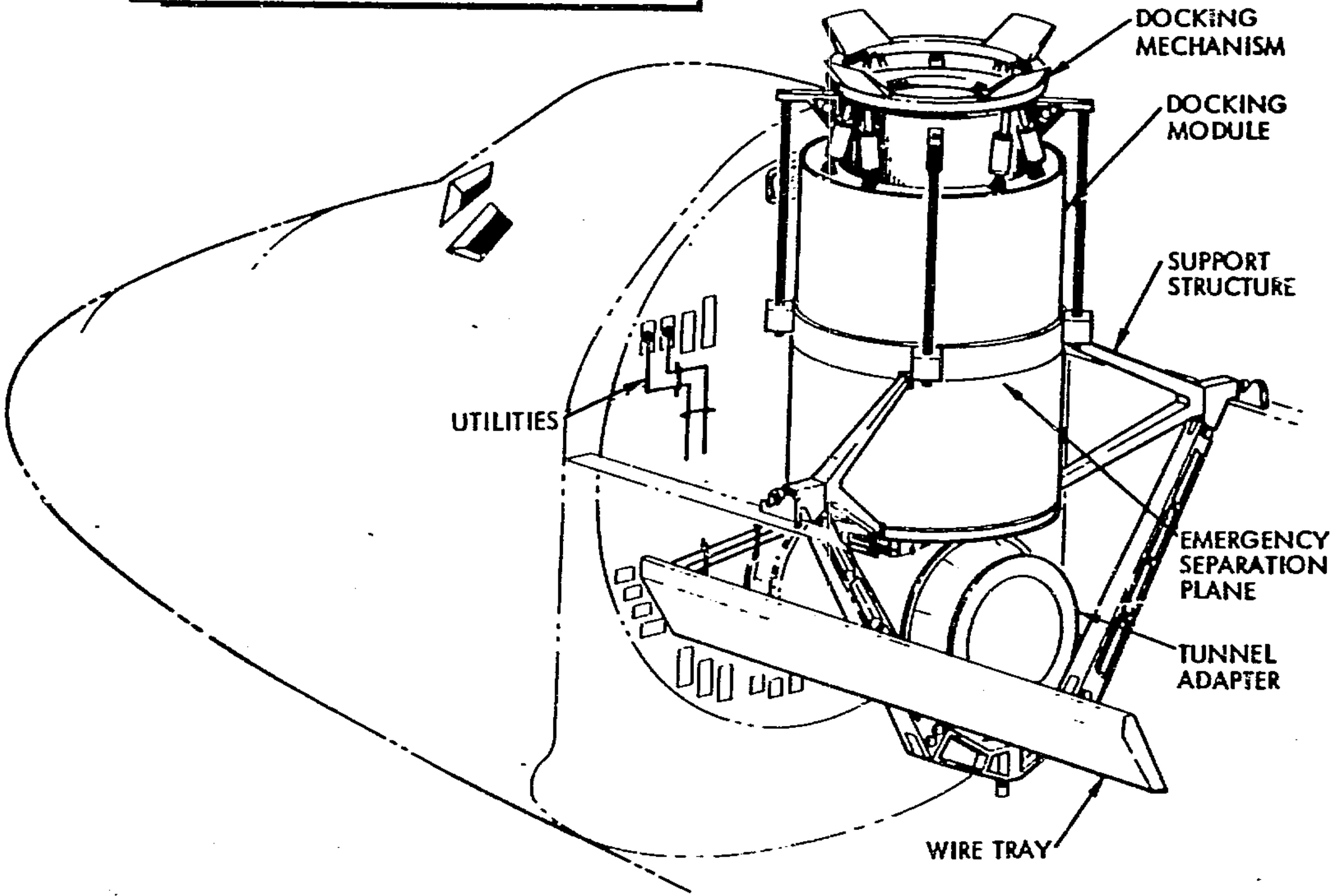


DOCKING MODULE CONCEPT

This chart represents the standard interface concept that was defined. The interface is shown mounted to an orbiter docking module concept that was also defined in this task.

DOCKING MODULE CONCEPT

STANDARD INTERFACE IS FEASIBLE



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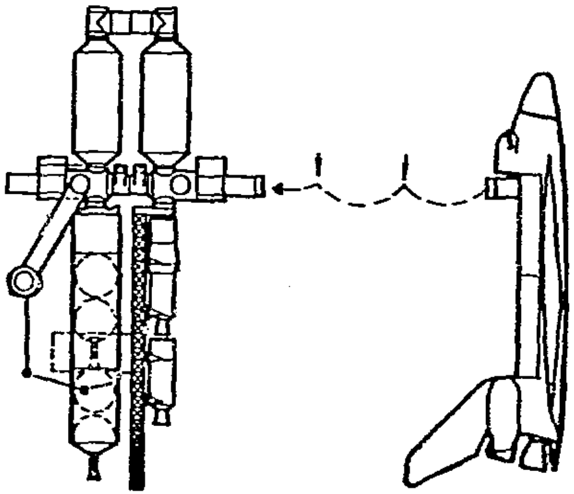
DOCKING TRAJECTORY ACCURACY

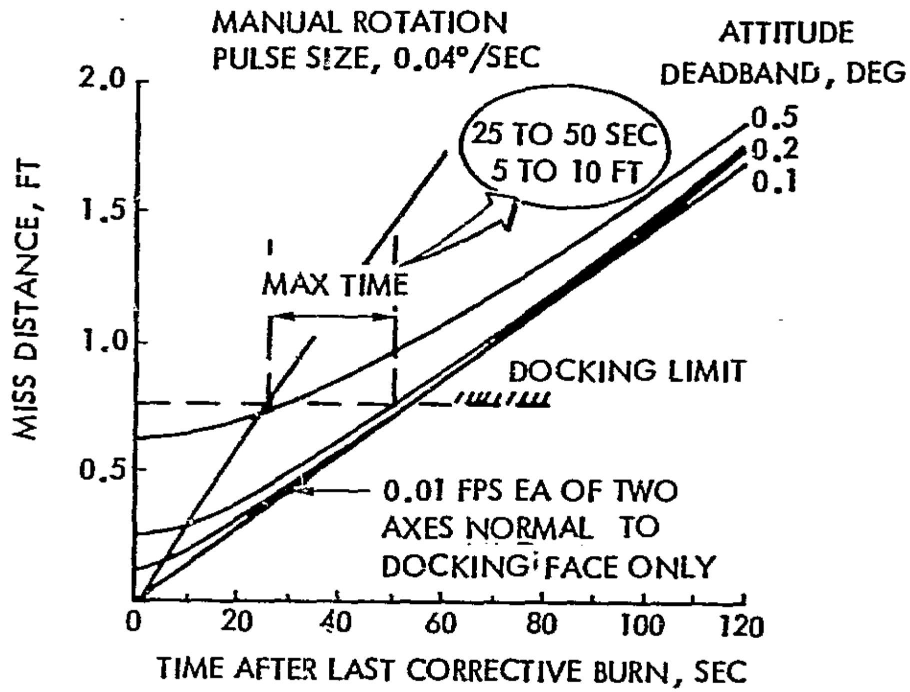
The orbiter mating analysis also verified the capability of the orbiter to safely perform the direct docking maneuver. This chart indicates the capability of the RCS to control the approach maneuvers within the 9 inch docking misalignment criteria.

DOCKING TRAJECTORY ACCURACY

"ORBITER CAN DO THE JOB"

- PROXIMITY RCS FIRING REQUIRED
- MOSTLY X_B & Y_B CORRECTIONS..... WITH SOME ROTATIONAL HOLD ATTITUDE FIRINGS





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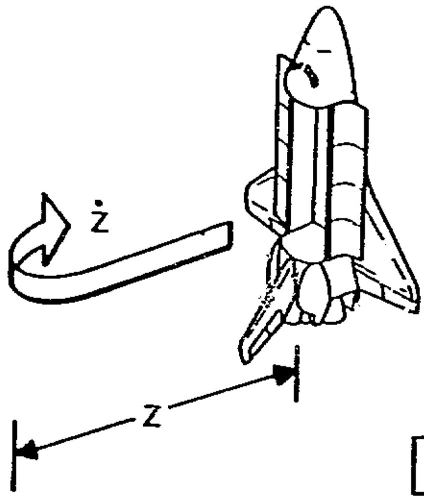
DOCKING ABORT TURNAROUND

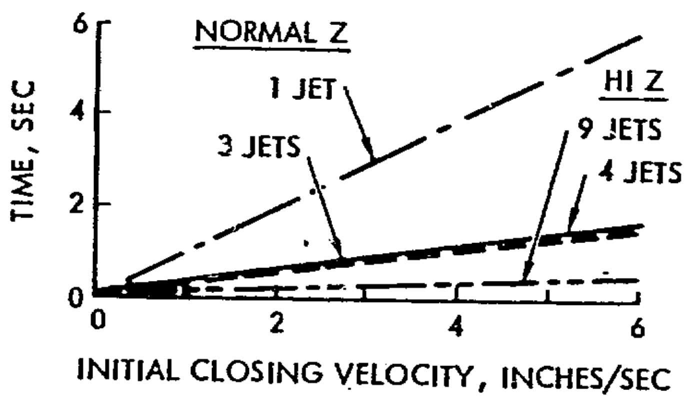
The possible orbiter runaway jet condition was analyzed with the determination that the RCS hi-z thrust mode has the capability to control this anomaly and safely perform an abo-t maneuver. This chart indicates the stopping times and distances that can be achieved which justifies the hi-z thrust mode.

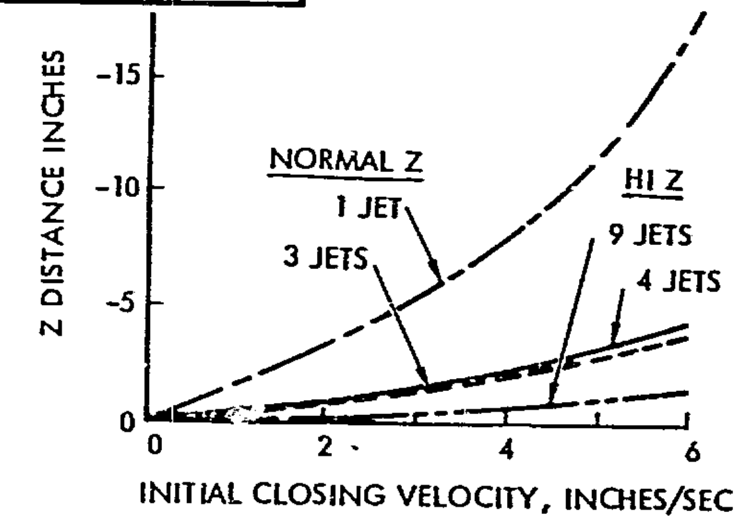
DOCKING ABORT TURNAROUND

RUNAWAY JETS CAN BE CONTROLLED



TIME & DISTANCE TO REVERSE $\dot{Z}$ AT THE DOCKING PORT



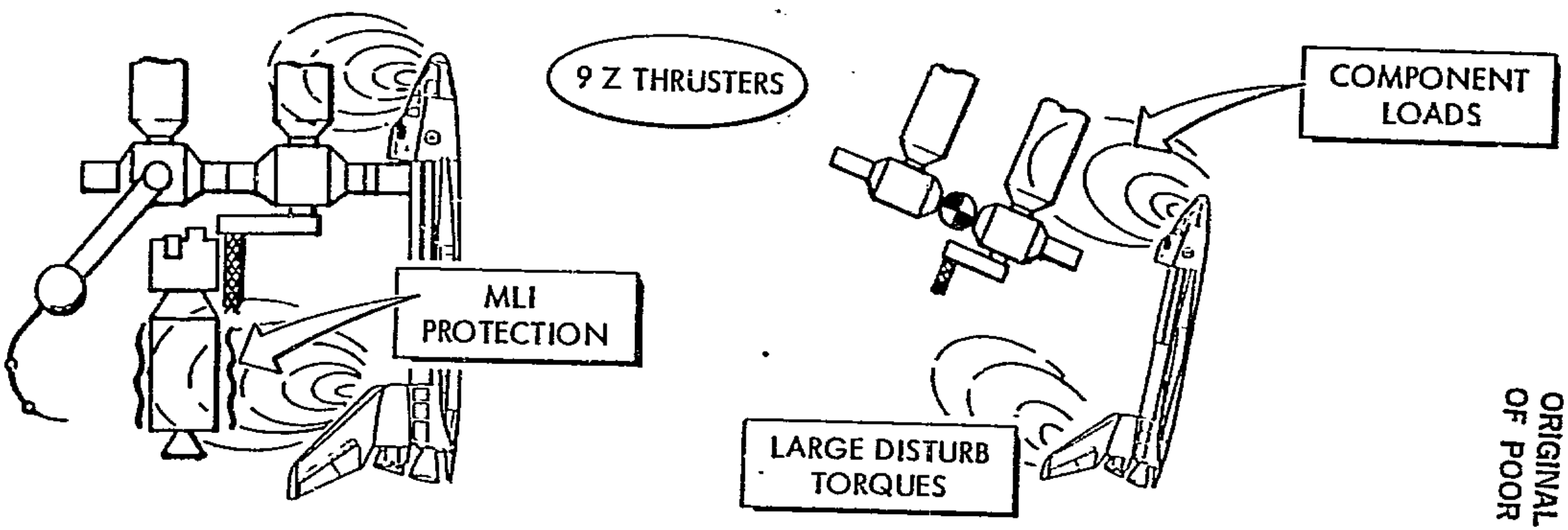


RCS PLUME ANALYSIS

The RCS plume implications to the SOC, and possibly other vehicles attached to it, are illustrated in this chart. The following table summarizes the forces, moments, heat rates, and particulate deposition rates that occur as the result of the run-away jet abort maneuvers.

RCS PLUME ANALYSIS

DESIGN SOC FOR HI-Z ABORT THRUSTING PLUME



RCS PLUME IMPINGEMENT SUMMARY

DESCRIPTION	MASS* DEPOSITION RATE (lbm/sec)	SOC IMPINGEMENT FORCES (lbf)			SOC MOMENTS (lbf-ft)			CONVECTIVE HEATING RATE (Btu/sec)
		F_X	F_Y	F_Z	M_X	M_Y	M_Z	
FWD RCS, 3 ENGINES (+Z DIRECTION)								
HABITABILITY MODULE NO. 1	3.146	981.1	0	41.8	0	24,058.1	0	7730.0
LOGISTICS MODULE	0.272	59.7	-11.7	-60.6	809.0	-508.2	699.0	637.7
SERVICE MODULE NO. 1	0.266	41.2	0	-29.0	0	-289.4	0	609.9
TOTAL	3.684	1082.0	-11.7	-47.8	809.0	23,260.5	699.0	
AFT RCS, 6 ENGINES (+Z DIRECTION)								
PARKED PLANETARY VEHICLE	0.354	90.6	0	50.8	0	-5,195.7	0	773.2
SAM**	2.564	867.2	0	-70.2	0	-67,579.0	0	6540.6
R/CM MODULE	0.280	60.0	23.5	39.2	1758.7	-3,255.6	-747.9	569.8
TOTAL	3.198	1017.8	23.5	19.8	1758.7	-76,020.3	-747.9	
-Y THRUSTER, 1 ENGINE								
SOLAR ARRAY (≈ 52° ANGLE)	0.720	116.7	-171.4	-45.1	6018.4	-1957.3	19,554.1	1659.8
4.3 M ANTENNA (-Y DIRECTION)	0.036	3.2	-5.4	-0.4	123.2	55.2	220.6	45.9
RADIATORS (-Y DIRECTION)	0.009	2.3	-1.4	-0.5	35.1	20.3	79.0	20.6
TOTAL	0.765	122.2	-178.2	-46.0	6176.7	-1881.8	19,853.8	

*NOTES: (1) ONE ENGINE PRODUCES 870 lb_f THRUST
(2) MASS FLOW RATE OF ONE ENGINE—3.01 lbm/sec
(3) MASS FLUX CONTAINS APPROX 9% CO_2, 17.5% CO, and 29.2% H_2O

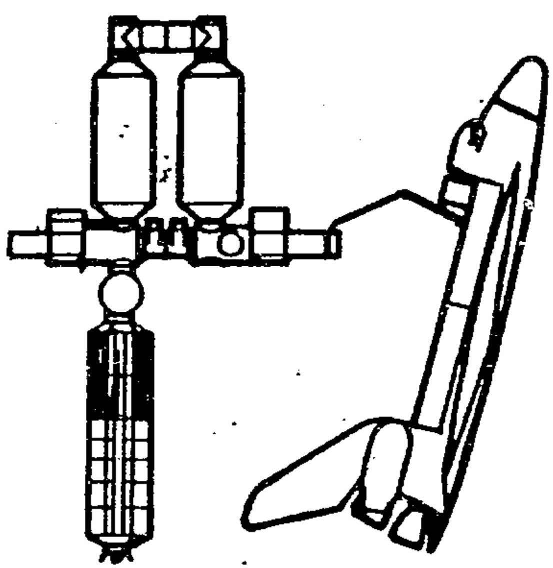
**ASSUMED THAT THE SAM WAS OPAQUE (INTERNAL PARTS STOWAGE)

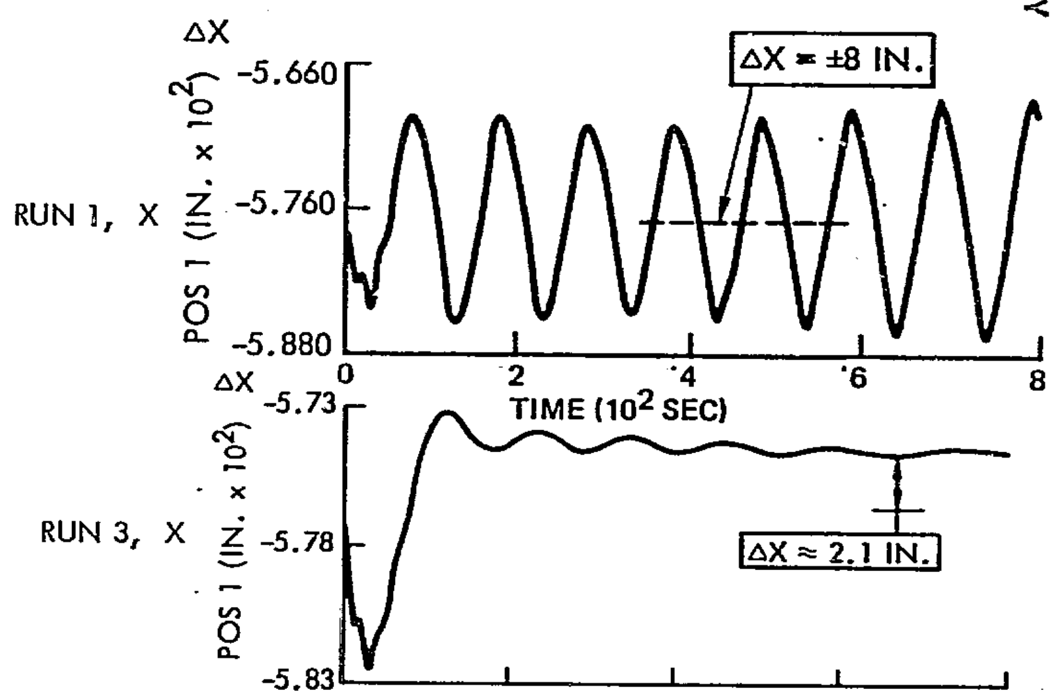
SHUTTLE BERTHING

The capability to berth the orbiter to a full-up SOC utilizing the orbiter RMS was verified with the simulations performed by SPAR of Canada. The simulations, however, indicated most software modifications to the RMS control logic would be necessary in order to damp out the relative oscillations between the two masses, the orbiter and the SOC. Run 3 represents the influence of the control software modifications.

RMS SOFTWARE MODIFICATIONS
REQD FOR BERTHING ORBITER TO SOC

BERTHING OPERATIONS





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PROPELLANT DELIVERY

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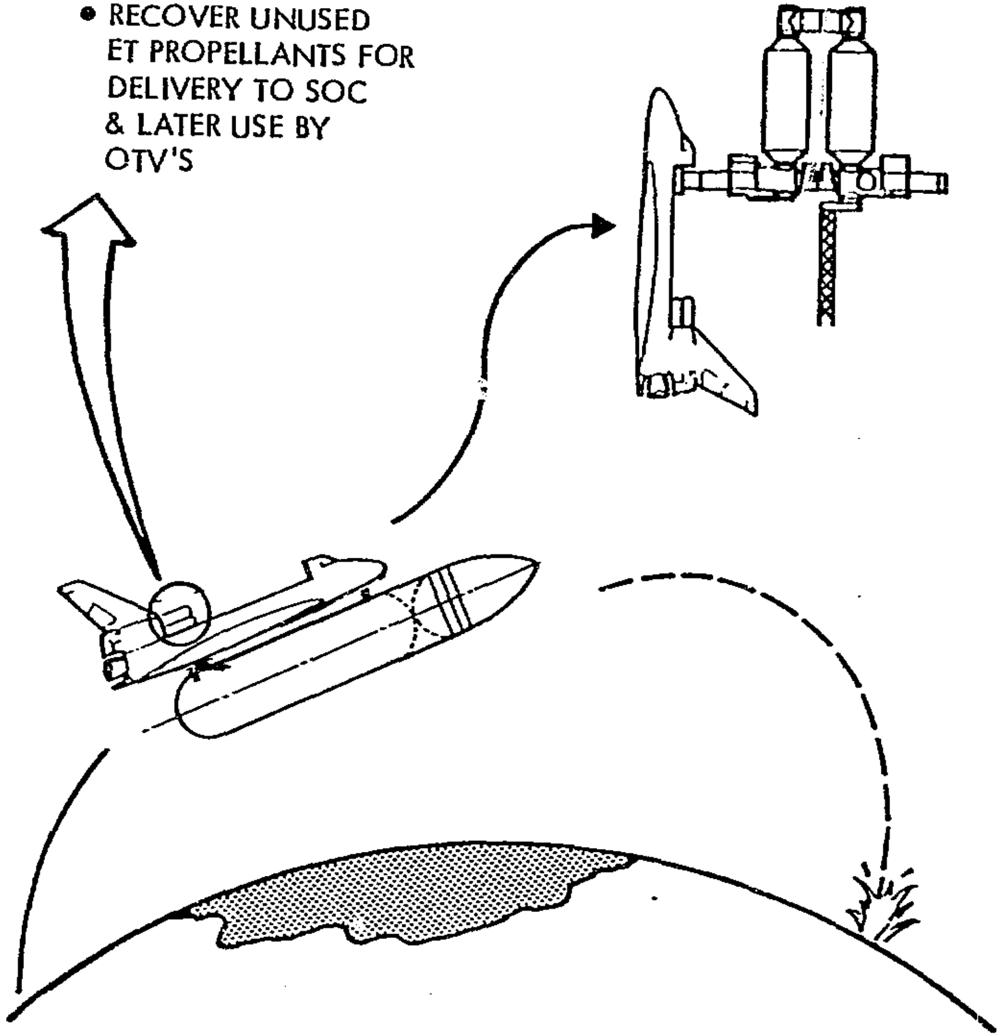
E.T. PROPELLANT SCAVENGING

The E.T. Propellant Scavenging concept was reviewed in detail at the October 1981 briefing, considering the issues as listed on the chart. This analysis provided the rationale for the statement that "Propellant Scavenging is feasible." This concept makes a wide range of scavenging scenarios possible as illustrated in the following chart. Three basic scenarios are shown, (1) basic scavenging associated with full payload bays, (2) propellant top-off to bring the manifest to near 100% efficiency and (3) a dedicated tanker configuration.

ET PROPELLANT SCAVENGING

PROPELLANT SCAVENGING IS FEASIBLE

- RECOVER UNUSED ET PROPELLANTS FOR DELIVERY TO SOC & LATER USE BY OTV'S



ISSUES CONSIDERED

- ✓ ET DISPOSAL
- ✓ MECO TRANSIENTS
- ✓ ULLAGE THRUSTING OPTIONS
- ✓ PRESS VS PUMPED TRANSFER
- ✓ PAYLOAD IMPACTS
- ✓ TANKS & PLUMBING CONCEPTS
- ✓ CREW & SAFETY CONSIDERATIONS

SCAVENGING ANALYSIS SUMMARY

ET PROPELLANT SCAVENGING IS FEASIBLE ✓

WIDE RANGE OF SCAVENGING SCENARIOS ARE POSSIBLE ✓

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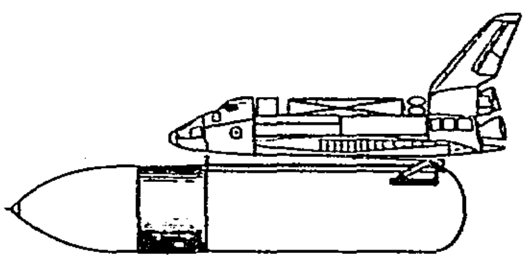
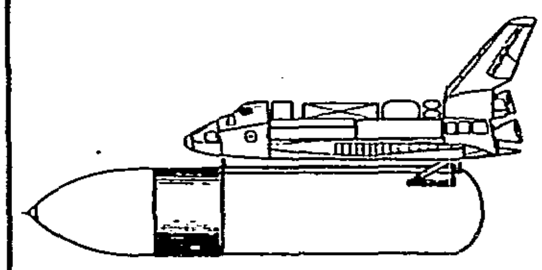
- BASIC SCAVENGING



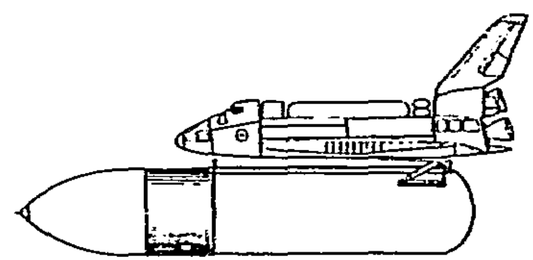
$w_P \approx$ 10-15K LB

- P/L TOP-OFF



$w_P \approx$ 30-40K LB

- DEDICATED TANKER



$w_P \approx$ 70 + KLB

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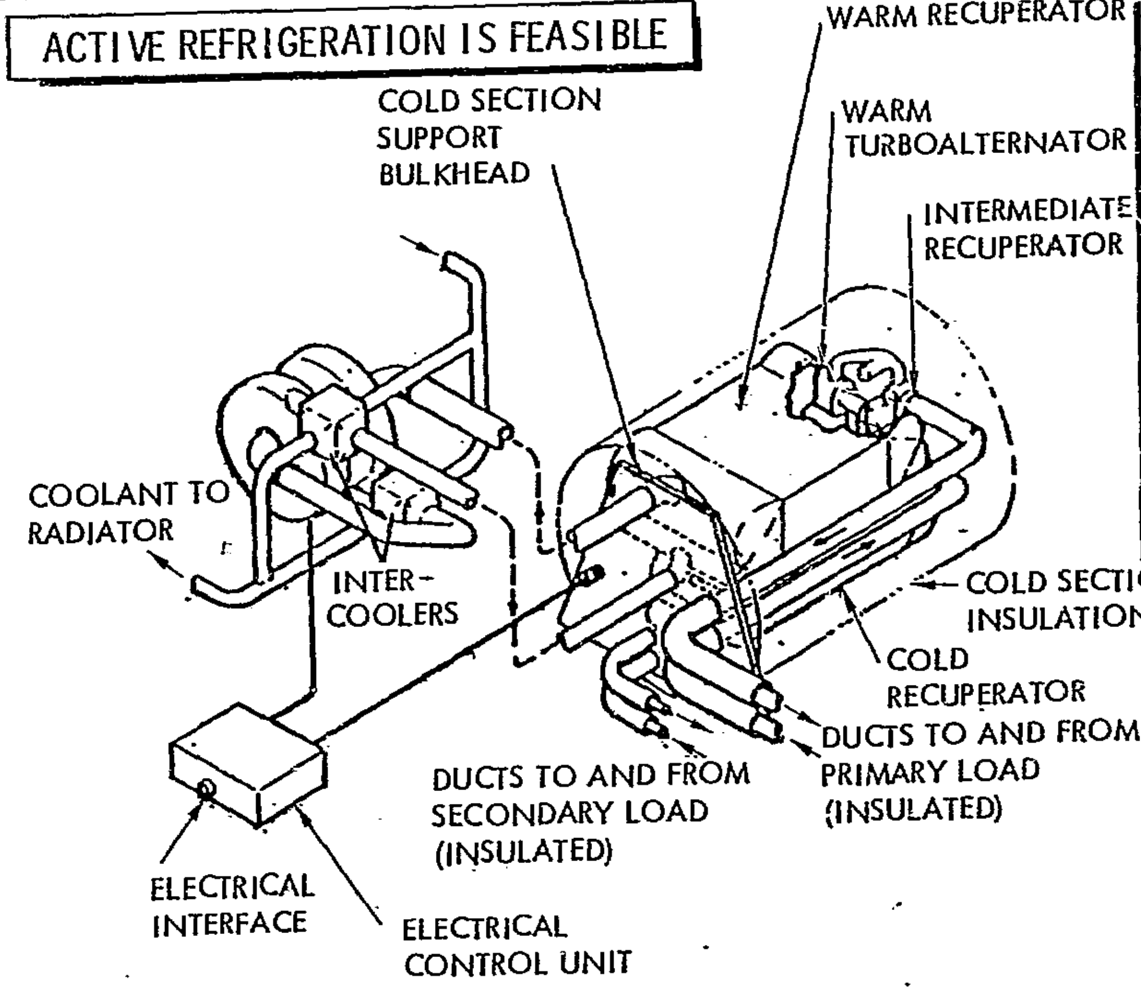
BRAYTON TURBO REFRIGERATOR SCHEMATIC

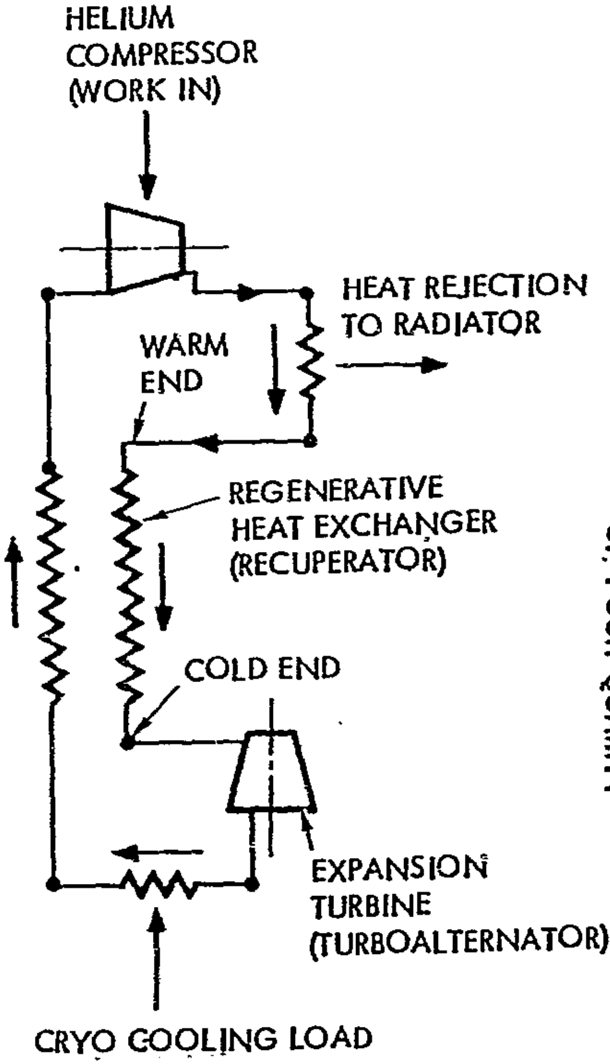
Propellant storage on the SOC is necessary in order to capitalize on the propellant scavenging concept. Retaining the propellant in a sub-cooled state is desireable. This condition can be achieved with an active refrigeration system as illustrated on this chart. The electrical power requirements are minimal as indicated on the following chart. Sub cooling the propellant also has the benefit of reducing the amount of insulation required on the using OTV which will contribute to the performance of the OTV.

BRAYTON TURBO REFRIGERATOR SCHEMATIC

ACTIVE REFRIGERATION IS FEASIBLE



MINI-HALO COMPONENT ARRANGEMENT



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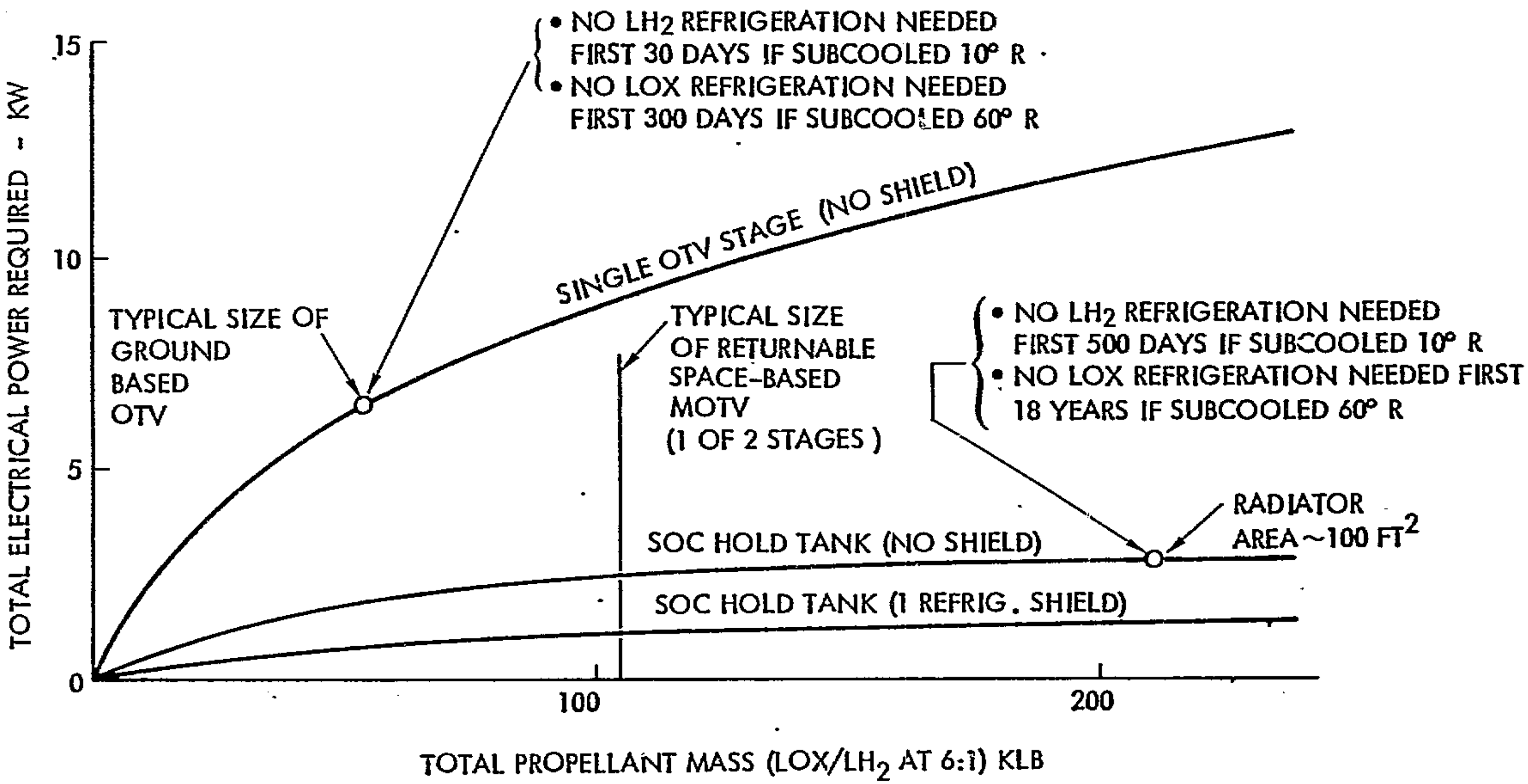
CRYO PROPELLANT REFRIGERATION POWER

MINIMUM POWER REQUIRED

- 6:1 LOX/LH_2 TANKAGE
- TURBO BRAYTON HELIUM REFRIGERATOR
- 200 N.M. SOC ALTITUDE

- MLI TANK INSULATION
- 450° R @ OUTER MLI LAYER
- ~90% OF POWER REQUIRED IS FOR LH_2 TANK



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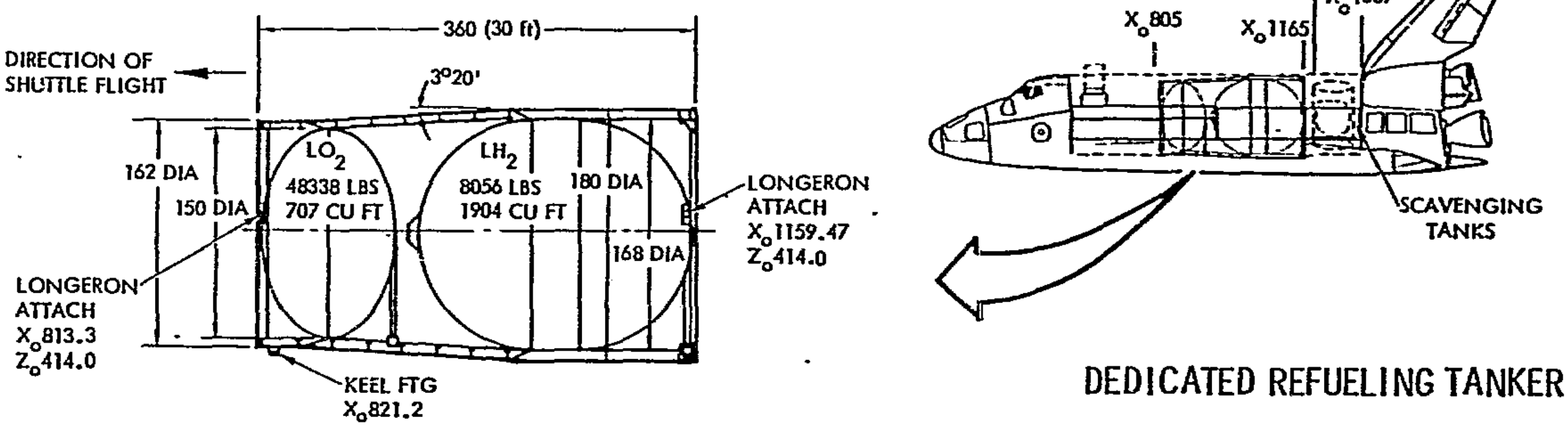
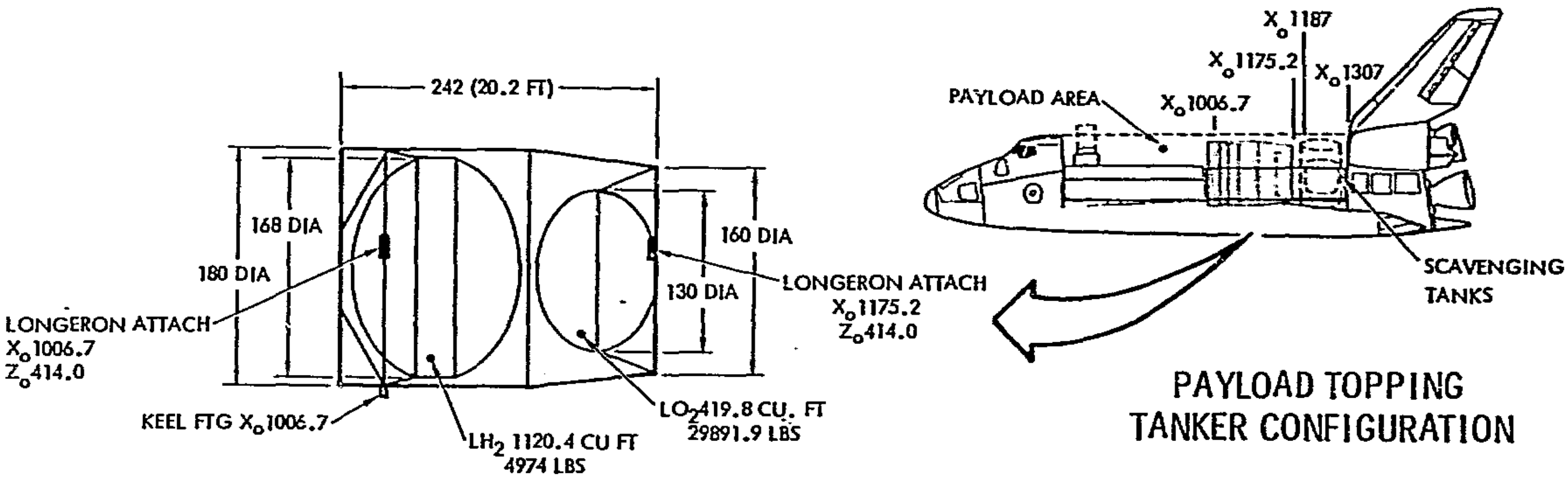
CRYO TANK CONCEPTS

In this analysis we've identified propellant storage tanks for three areas, shuttle scavenging, top-off and dedicated tanker; SOC storage; and for OTV's. Preliminary indications are that a standardized tank concept is feasible for these applications and certainly would be desireable. Variations in capacity could be achieved by adding or increasing the cylinderical section of the tanks only.

CRYO TANK CONCEPTS



DEDICATED REFUELING TANKER



PAYLOAD TOPPING TANKER CONFIGURATION

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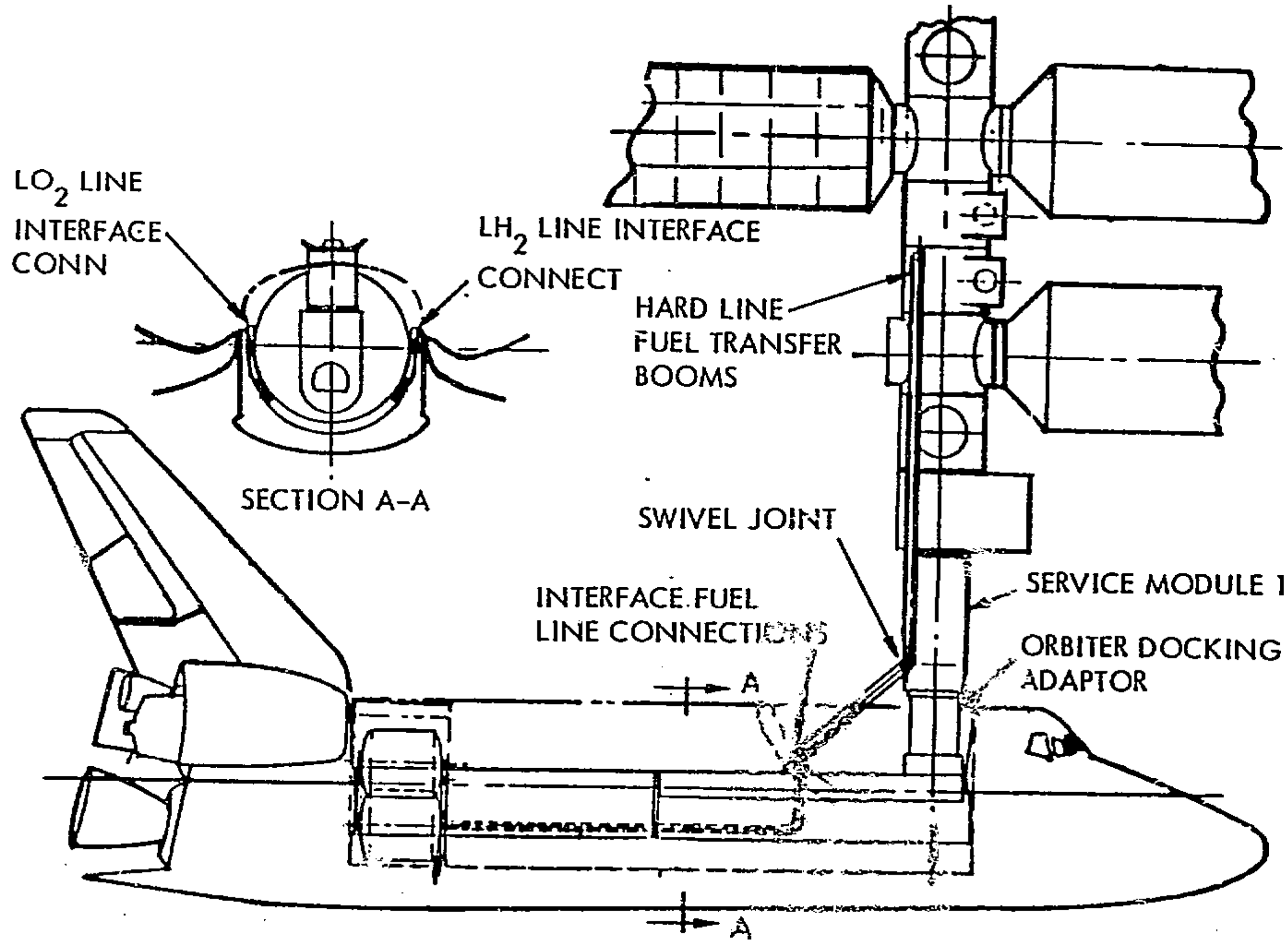
ON-SITE FUEL TRANSFER CONCEPT

A standard propellant transfer interface between the orbiter and the SOC would be desireable. It is too early at this time to know the total complications of implementing such as a design because of the unknown locations of the top-off tanks in relationship to maintaining the orbiter c.g. limits.

ON-SITE FUEL TRANSFER CONCEPT

STANDARD TRANSFER INTERFACE DESIRABLE



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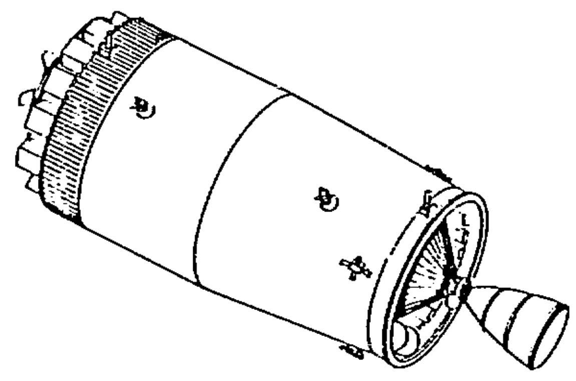
SPACECRAFT SERVICING

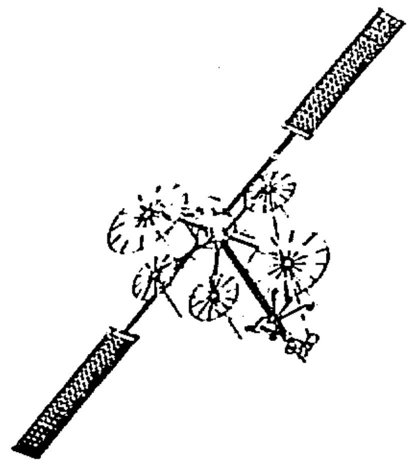
REPRESENTATIVE SPACE CRAFTS

A comparison of servicing costs and check-out logic was the principal objective of this task. The representative spacecraft that were used to analyze this task are shown here and the servicing locations that were compared are also indicated. Servicing functions for each of the spacecraft were determined and the manhours and the unique equipment required to perform the functions at the respective servicing areas were identified.

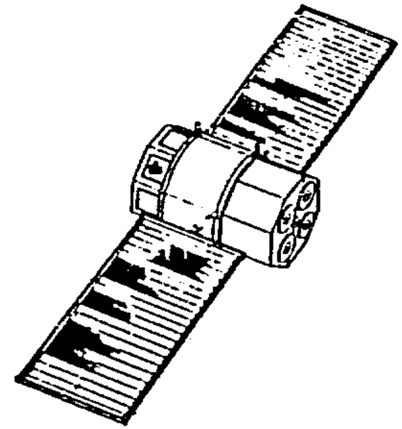
REPRESENTATIVE SPACECRAFTS



OTV



COMMUNICATION SATELLITE



SPACE PROCESSING FACILITY

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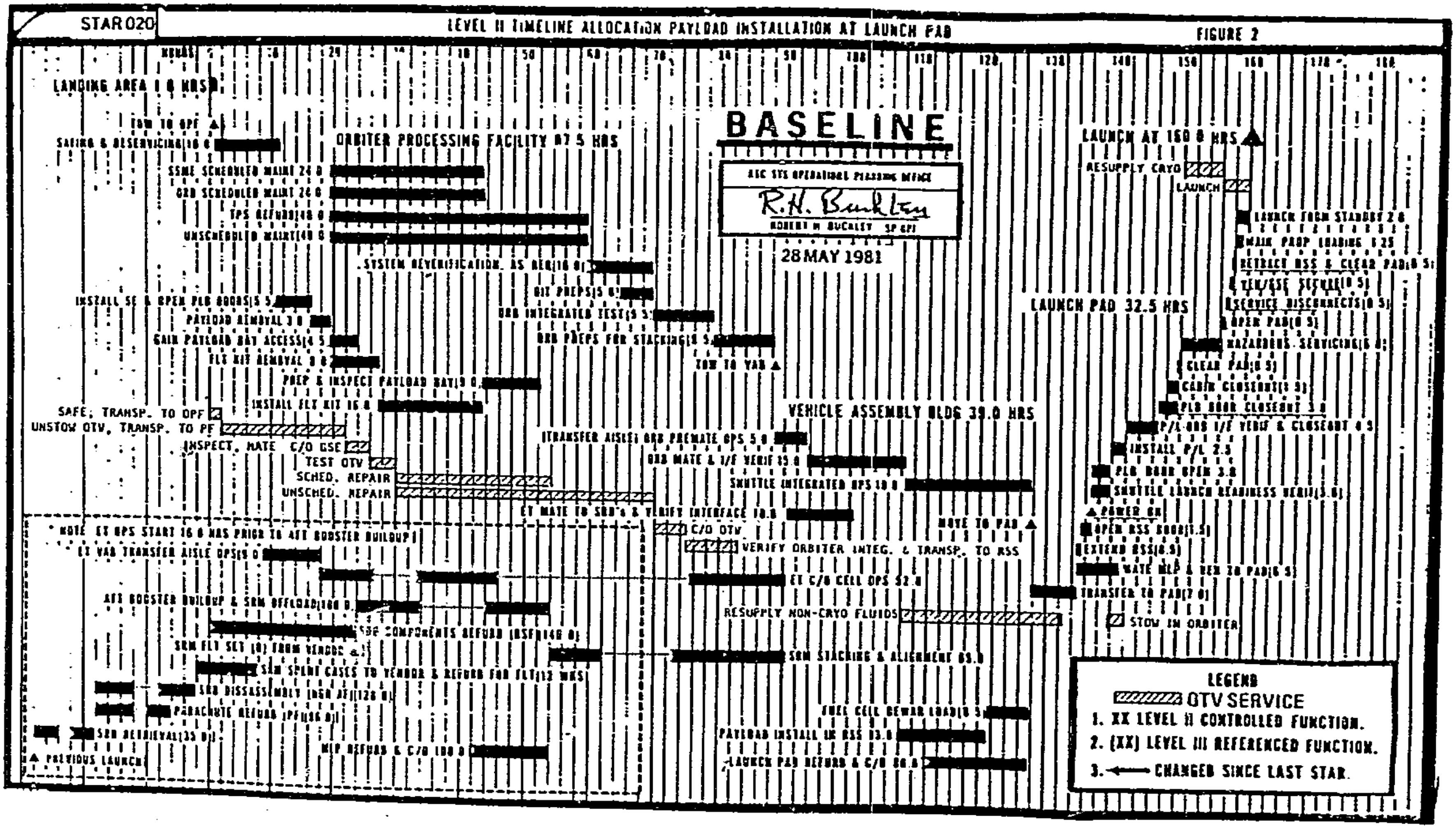
- FEATURES SIGNIFICANT TO SERVICING
  - LOADING OF FLUIDS
    - CRYOGENICS – LO_2, LH_2
    - NON-CRYOGENICS – He, GN_2, HYDRAZINE
  - MODULE & COMPONENT EXCHANGE OPS
  - EXTENSIVE DEPLOYMENT & C/O OPS
  - FREQUENT REVISITS
  - SMALL TO LARGE S/C

S/C	GROUND SERVICING	ORBITER SERVICING	SOC SERVICING
OTV	✓	N/A	✓
COMM SAT	N/A	✓ INITIAL ASSY & LAUNCH TO GEO	✓ INITIAL ASSY & LAUNCH TO GEO
SPACE PROCESSING FACILITY	N/A	✓	✓

OTV SERVICING TIMELINE

Many of the servicing functions time allocations were determined by engineering judgement because of the lack of any firm data. However, where data did exist for comparable operations it was used. An example of this is shown here where a servicing timeline for an OTV serviced on the ground is shown superimposed on the shuttle turnaround schedule.

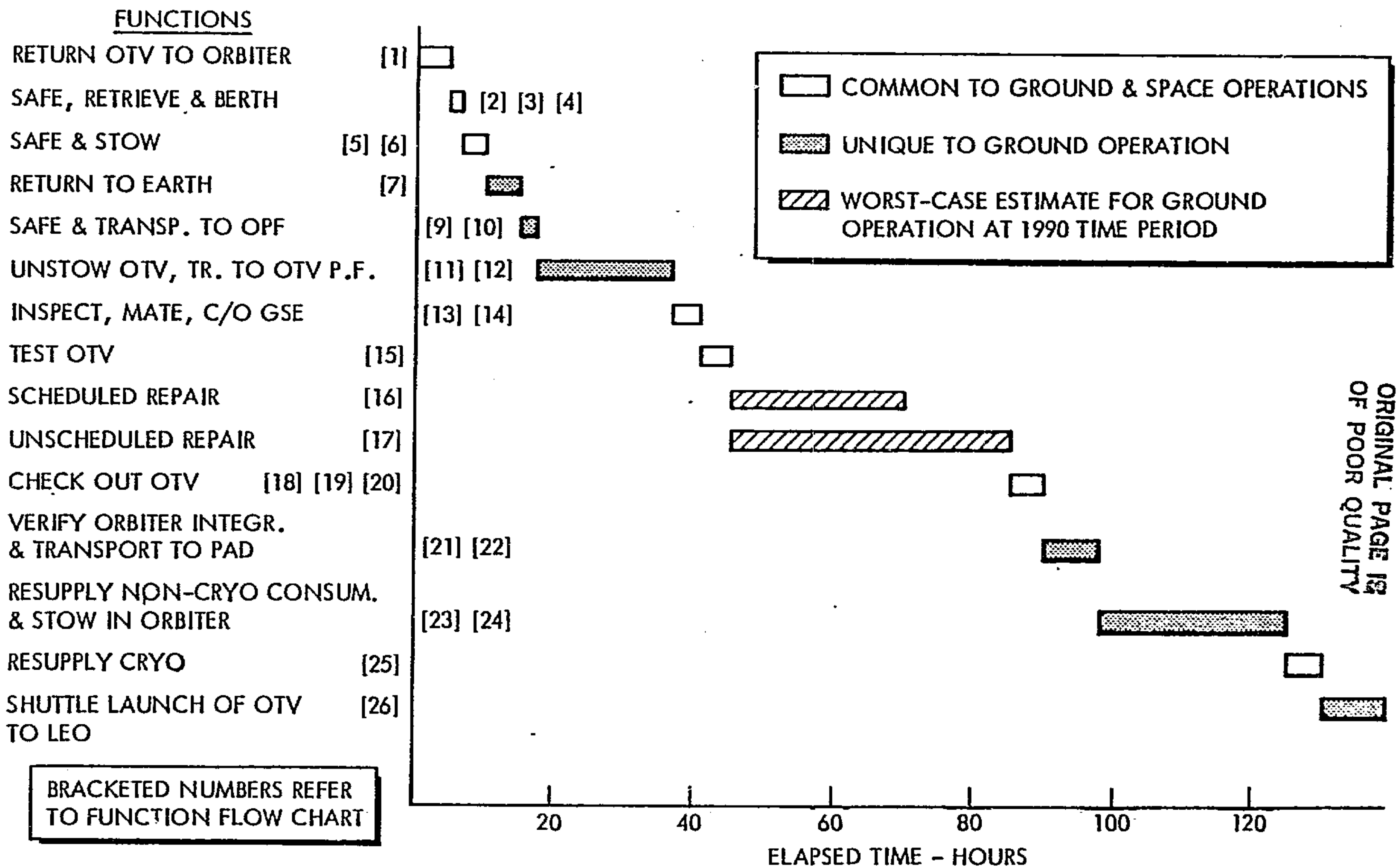
OTO SERVICING WITHIN SHUTTLE TURNAROUND SCHEDULE



TIMELINE ANALYSIS OF OTV GROUND TURNAROUND SHOWING UNIQUE DIFFERENCES FROM SPACE OPERATIONS

The greatest variation in times is the comparison of the OTV servicing operations. This OTV timeline chart shows the differences between ground and SOC servicing. The major differences occur as a result of OTV handling from retrieval at LEO, and the pad operations of refueling.

TIMELINE ANALYSIS OF OTV GROUND TURNAROUND SHOWING UNIQUE DIFFERENCES FROM SPACE OPERATIONS



BRACKETED NUMBERS REFER TO FUNCTION FLOW CHART

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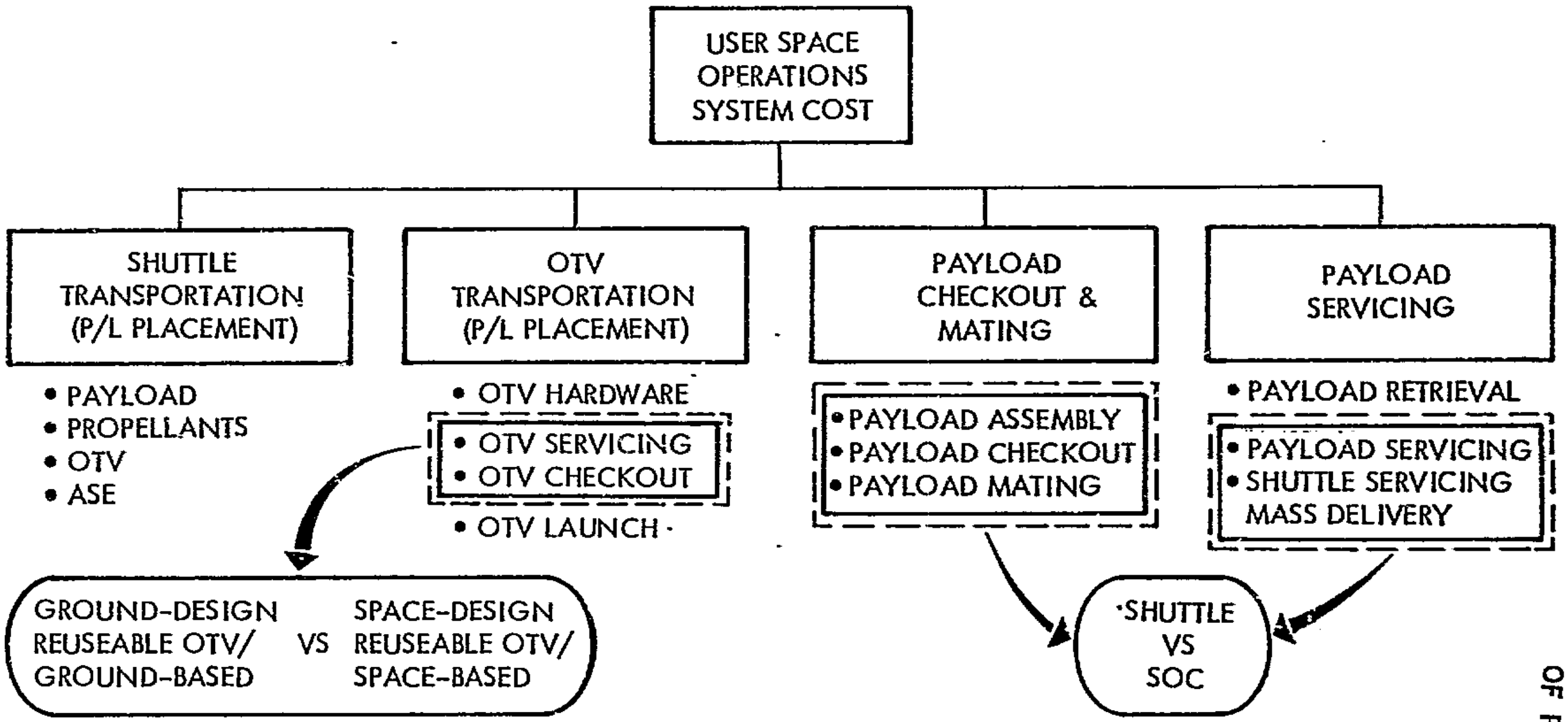
SERVICING COMPARISONS APPROACH

The elements of the cost comparison of the servicing operations are shown on this diagram. The spacecraft servicing task of this study, evaluated only those operations indicated by the frames. The ground rules that were utilized to generate the cost figures are also indicated.

SERVICING COMPARISONS APPROACH



GROUND RULES

- UNIT & OPERATIONS COSTS (DDT&E EXCLUDED – NATIONAL SECURITY INVESTMENT)
- COSTS IN FY 81 DOLLARS
- HARDWARE EXISTING FOR OTHER PURPOSES NOT COSTED
- LABOR COST ESTIMATES BASED ON:
  - ESTIMATED MAN-HOURS
  - DERIVED HOURLY CHARGES

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COMPARISON SUMMARY

A summary of the comparison items are shown on this chart. The costs per servicing operation are shown as well as the user costs over an 11 year period, 1990 to 2000. Even through the difference in manhours to perform the servicing operations are small, except for the OTV Servicing, the costs per servicing and the 11 year users costs favor the SOC servicing operations.

COMPARISON SUMMARY

	EVALUATION FACTORS								
	NO. OF UNIQUE EQUIPMENT	ELAPSED TIME (HRS)	MAN-HOURS	NO. CREW	** EQUIPT COST($M)	LABOR COST($M) PER SERVICING	ORBITER FLIGHT COST ($M)	NO. OF SERVICING MISSIONS	USER 11-YEAR OPERATIONAL COST ($M)
SPACE BASED OTV	3	57.3	193.7	3-5	8.5	4.72	–	172	820
GROUND BASED OTV	5	140	600	3-6	27	2.76	3.56	331	2119
COMM-SAT-SOC	2	61.0	200	2-5	0.3	4.88	–	92	449
COMM-SAT-ORBITER	2	50.8	165	2-4	3.5	7.34	3.56	251	2739
SPF - SOC	3	29.6	103	3-4	14.2	2.51	8.73	110	1251
SPF - ORBITER	4	27.5	106	2-4	9.6	4.72	16.1	110	2300

** LESS DDT & E

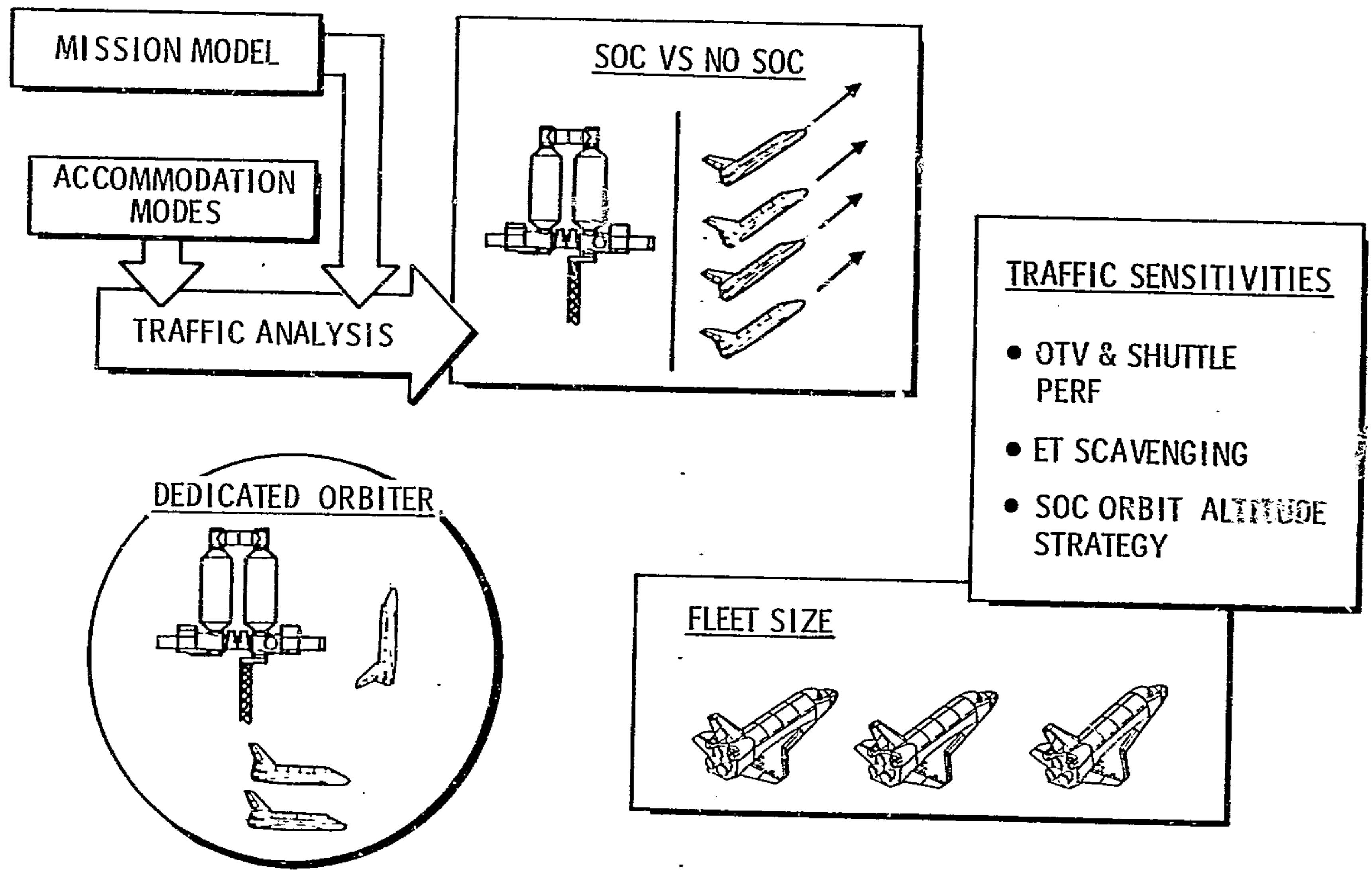
MISSION/TRAFFIC MODEL

SHUTTLE FLEET UTILIZATION AND PROGRAMMATICS

This task has as its objective the determination of the shuttle fleet size, the determination of the traffic sensitivities from changes to OTV and shuttle performance implications of propellant scavenging, and SOC orbit altitude implications.

The derivation of this information requires the determination of a mission model. Low, medium, and high intensive mission models were generated. Accommodations of the mission model were defined for two programs without the SOC, C and C2, and one with the SOC, A. Shuttle manifests were determined and appropriate traffic models developed. The rational for the use of a dedicated orbiter for the SOC accommodation mode was also developed.

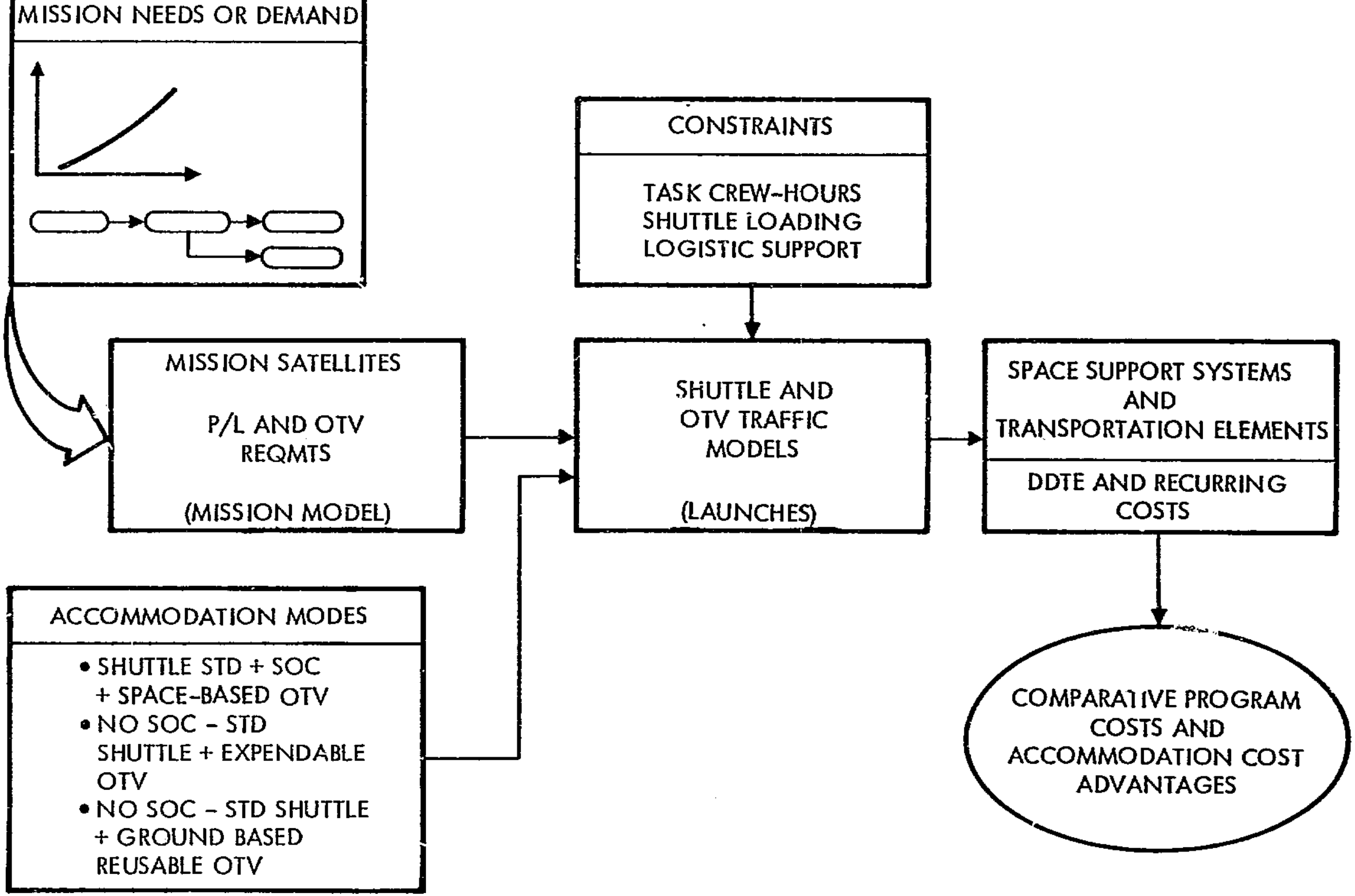
SHUTTLE FLEET UTILIZATION AND PROGRAMMATICS



MISSION MODEL -- ACCOMMODATION TRADES

In the establishment of the Shuttle and OTV traffic models, the analysis begins with the mission models that reflect user needs and their anticipated frequency of demands. Each mission area has been reviewed individually to establish the most reasonable grouping of mission needs into low, medium, and high mission area requirements. Each mission area is not driven by the same factors. Growth is experienced at different rates and for varying rationale in each mission area.

These mission needs, when analyzed with the mission satellites which are the payload and OTV requirements, together with the three accommodations modes, form the basis for the three mission models: low, medium, and high. The accommodations of these requirements, together with the constraints such as crew hours, Shuttle loading capability, and logistic support constraints established the Shuttle and OTV traffic models. Evaluation of the traffic models for each of the three accommodation modes determined the required amount of support system hardware (OTV's, Shuttles, logistics models, etc.) and it provided the basis for the comparative program costs and as a discriminator in the establishment of alternate accommodation mode cost advantages.



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MEDIUM MISSION MODEL SUMMARY -- SOC INTERACTION, 1990-2000

For each of the SOC interaction mission areas, the number of spacecraft or mission element payloads and their packaging characteristics for the years 1990 to 2000 are shown. These summary data illustrate the variety of payloads and their accumulated weights over the 11-year period that must be transported to SOC. These payloads as defined in the mission model are manifested by cargo elements to generate the STS traffic modes that have been described in the previous charts.

The rationale for the selection of the number and size of payloads in each category is listed below:

Commercial Communications	– Demand projections are the result of a survey of U.S. commercial users plus an assessment of international requirements.
DOD GEO Payloads	– Air Force provided the source materials. Adjustments were made for the existence of SOC and for estimated growth potential.
NASA Planetary	– Selected NASA missions planned for 1986-2000.
Space Processing	– Based on development logic starting with Ø1 experiments, 30% go to Ø2 process development, with 50% progressing to Ø3 production development and commercial production.
NASA R&D, Life Science	– Selected missions from NASA Science and Applications Plans.
Satellite Servicing	– Servicing operations for NASA Science and Applications Satellites.
Space Construction	– Selected two candidate large satellites to be operated in GEO.

MEDIUM MISSION MODEL SUMMARY
SOC INTERACTION 1990-2000

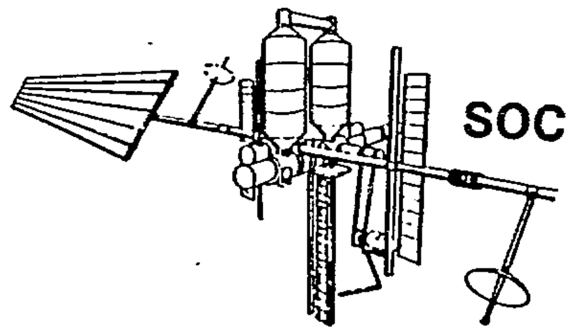
MISSION AREA	NO. OF P/L REQUIRED	TYPES OF P/L NO. REQD, CARGO BAY PACKAGING, & DESCRIPTION			TOTAL WEIGHT OF P/L DELIVERIES TO SOC (KLBS)
COMMERCIAL COMMUNICATION	92	34	26 FT	12 K – 240 T Ka BAND	1104
		58	44 FT	12 K – 240 T C, Ku, & Ka BANDS	
DOD GEO PAYLOADS	74	24	LOW ρ	3 – 7.5 K 12–30 FT	370
		33	MED ρ	3 – 7 K 10–22 FT	
		17	HI ρ	5 – 10 K 8–13 FT	
NASA PLANETARY	12	4	LOW ρ	1.2 – 7.7 K 6.5–16 FT	127
		8	HI ρ	24 – 19 K 3.3 – 22 FT	
SPACE PROCESSING.	285	99	φ I EXPERIMENT	99 SMALL PACKAGES – 1K EA	1466
		66	φ II PROCESS DEVELOPMENT	11 FLT TEST MISSIONS – 2K EA 55 SERVICE MISSIONS – 1K EA	
		20	φ III PRODUCTION DEVELOPMENT	5 FREE FLY MISSIONS – 10K EA 15 SERVICE MISSIONS – 6K EA	
		100	PRODUCTION FACTORY	5 FREE FLY FACTORIES – 40 K EA 95 SERVICE MISSIONS – 10 K EA	
NASA R&D, LIFE SCIENCE	25	9	30 FT	30 K R&D LEO MISSIONS	622
		8	32 FT	32 K LIFE SCI MISSIONS	
		8	26 FT	12 K GROWTH – GEO S/C	
SATELLITE SERVICING	40	6	27 – 39 FT	26 – 39 K LOGISTICS FOR 40 SERVICING MISSIONS OF 7 S/C	155
SPACE CONSTRUCTION	2	1	49 FT	36.5 K PINHOLE X-RAY TELE	46
		1	13 FT	9.5 K DEEP SPACE RELAY STA	

ALTERNATE ACCOMMODATION MODES OPTIONS DEFINITION

Three accommodation modes were selected for the cost effectiveness trends and analyses. The modes are characterized initially by the prime system considered. In the first option (A-1), the SOC was selected as the prime system to support payloads and the other mission area drivers. In the second set of options, (C-1 and C-2) the prime system was the Shuttle. Within each option there are a number of factors which are further considered to establish definite modes. The OTV system of a space design reusable OTV (Option A-1) was sized by the delivery of 12,000 pounds to geosynchronous orbit. The design characteristics of each OTV are listed. The spectrum of propellant sources ranged from Shuttle top-off and external tank transfer to propellant delivery with the OTV. In option A-1 payload checkout and mating with the OTV is accomplished at SOC.

The different accommodation modes were selected to provide a data base for an evaluation of the most reasonable spectrum of viable options to establish the key issues that must be addressed and evaluated. They also serve as the definition of the factors that provide the cost comparisons between options.

- **PRIME SYSTEM**

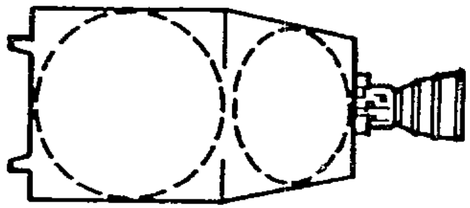


OPTION: A

- **OTV SYSTEM**

SPACE-DESIGN
REUSABLE
12K TO GEO

- **OTV DESIGN CHARACTERISTICS**
  - L = 30.2 FT
  - DIA = 14.5 FT
  - W_P = 48.4 KLB
  - W_{ST} = 53.4 KLB



- **PROPELLANT SOURCES**
  - SHUTTLE TOP-OFF
  - EXTERNAL TANK TRANSFER
- **P/L C/O**
  - P/L - OTV MATING & C/O AT SOC

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ALTERNATE ACCOMMODATION MODES (CONTINUED)

In these two accommodation modes, C-1, C-2, the prime system was the Shuttle. The OTV system in these two options is characterized by ground-designed OTV systems. Option C-1 utilizes a ground design expendable OTV and C-2 incorporated a ground design reusable (single Shuttle flight) OTV. The expendable OTV is capable of delivery of 12,000 pounds to GEO and the reusable OTV (option C-2) provides 7,000 one way with stage return. Again, the individual OTV design characteristics are listed on the chart. It should be noted, however, that the expendable OTV provides a much smaller (24 foot long) length design and has less of a propellant requirement - 24,000 pounds of fuel vs. 42,000-48,000 pounds for the other OTV option. In both of these cases, propellant delivery is with the OTV. Payload mating and checkout is either on the ground or with the Shuttle at LEO.

In these two options the manpower to mate the payload and OTV and conduct the checkout are provided by the orbiter crew (four men). Analysis of the crew hours required to accomplish the total mission area payload requirements were established and evaluated to compare the capability and total costs of the Shuttle-only options and the SOC options.

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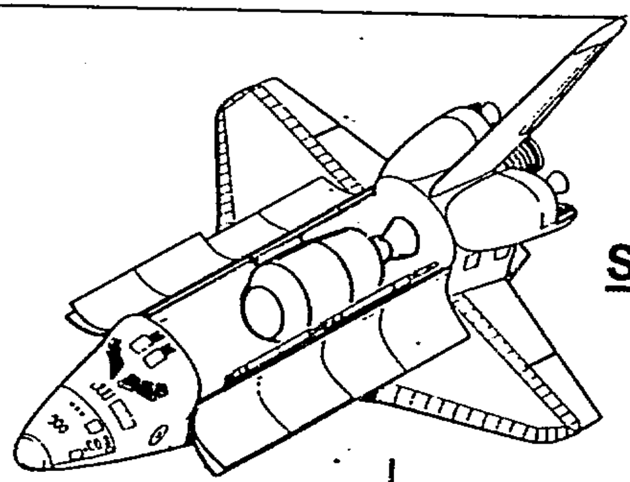
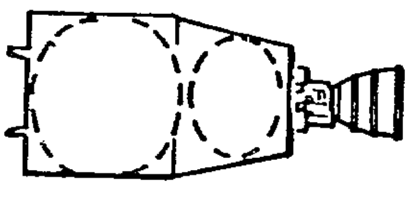
• **PRIME SYSTEM**

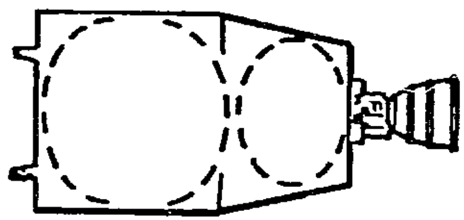


SHUTTLE
- 4 MAN
- 10 DAY ORBITER

OPTION:

	C-1	C-2
• OTV SYSTEM	GROUND-DESIGN EXPENDABLE 12K TO GEO	GROUND-DESIGN REUSABLE SINGLE-SHUTTLE FLIGHT 7K TO GEO
• OTV DESIGN CHARACTERISTICS	L = 24 FT DIA = 13 FT WP = 24.0 KLB W_{ST} = 26.9 KLB	L = 28.3 FT DIA = 14.5 FT WP = 42.3 KLB W_{ST} = 47.4 KLB
• PROPELLANT SOURCES	PROPELLANT DELIVERY WITH OTV	PROPELLANT DELIVERY WITH OTV
• P/L C/O	P/L C/O IN SHUTTLE	P/L C/O IN SHUTTLE





OPTION A MISSION MANIFEST (TYPICAL)

A typical mission manifest is represented in this chart. The noted unused payload bay volume is utilized as propellant transport volume. The forward portion of the orbiter payload bay is allocated to the docking module and the 9 feet of the payload bay is allocated to the E.T. scavenging receiver tank assembly.

OPTION A MISSION MANIFEST (TYPICAL)

PAYLOAD CATEGORY	MISS	OTV	MASS (LB)	LENGTH (FT)	SHUTTLE FLIGHT NO.	CARGO MANIFEST (CODE: WEIGHT (K LB) / LENGTH (FT))
SOC						
SOC LOGISTICS	4	0	35,000	26	1 – 4	DM 4.5/7; LOG MOD 35/26; UNUSED 18/18; ET 2.5/9
OTV						
OTV DELIVERY NO. 2	1	0	5,020	25	5	DM 4.5/7; OTV 5/25; UNUSED 48./19; ET 2.5/9
TELEOPERATOR	1	0	11,000	20	6	DM 4.5/7; TELE 11/20; UNUSED 42/24; ET 2.5/9
COMMUNICATIONS						
US COMMERCIAL TYPE IV S/C	5	5	12,000	44	7 – 11	DM 4.5/7; S/C 12/44; ET 2.5/9
TYPE V S/C	1	1	12,000	26	12	DM 4.5/7; S/C 12/26; UNUSED 41/18; ET 2.5/9
FOREIGN TYPE IV S/C	2	2	12,000	44		
TYPE V S/C	1	1				
DOD						

- 11 YEARS OPERATIONS
- ALL MISSIONS AREAS
- PAYLOAD PHYSICAL CHARACTERISTICS AND MANIFESTING GROUNDRULES USED TO ESTABLISH 3 TRAFFIC MODELS
- UNALLOCATED LOAD FACTOR (LF) AND PAYLOAD VOLUME USED IN PROPELLANT TRANSPORT ANALYSIS (A)

TOTAL TRAFFIC MODEL - ALTERNATE A

This chart represents the traffic model developed for the accommodation mode utilizing the SOC. The first eight years represent the traffic without SOC, with the SOC becoming operational in 1990. This traffic model indicates 23 shuttle flights to SOC in 1990.

TOTAL TRAFFIC MODEL - ALTERNATE A

	YEAR																				
	82	83	84	85	86	87	88	89	SUM	90	91	92	93	94	95	96	97	98	99	00	SUM
KSC																					
FIRST SOC																					
SOC DELIVERY AND CHECK OUT								5	5												5
PROP STORAGE TANK DEL								2	2												2
SOC LOGISTICS								2	2	4	4	4	4	4	4	4	4	4	4	4	46
OTV TEST								1	1												1
OTV DELIVERY										2	2	2	2	2	2	1	2	3	2	2	22
25 KW MODULE						1		1	2												2
TELEOPERATOR										1											1
SUBTOTAL						1		11	12	7	6	6	6	6	6	5	6	7	6	6	79
COMMUNICATIONS																					
US COMMERCIAL	1	1	1	5	5	6	5	3	27	6	6	5	5	5	5	2	3	9	10	5	88
FOREIGN (50%)		1		3	3	3	2	2	14	3	3	2	3	2	3	1	1	5	5	3	45
SUBTOTAL	1	2	1	8	8	9	7	5	41	9	9	7	8	7	8	3	4	14	15	8	133
DoD PAYLOADS				5	2	1	3	5	16	3	7	5	5	5	3	3	6	3	4	4	64
NASA PLANETARY				1	3	1		1	6				3	3	2		3		1		18
SPACE PROCESSING		1	1	1	1	2	2	2	10	1	1	2	2	3	3	4	4	5	5	6	46
NASA R&D, LIFE SCIENCE				1	1	1	1	1	5	2	1	2	2	2	2	3	2	2	3	4	30
SATELLITE SERVICING				1	1	1	1	2	6	1			1			1			1	2	12
SPACE CONSTRUCTION															1		2				3
SUBTOTAL		1	1	9	8	6	7	11	43	7	9	9	13	13	11	11	17	10	14	16	172
TOTAL KSC FLIGHTS TO GEO NODE	1	3	2	17	16	16	14	29	96	23	24	22	27	26	25	19	27	31	35	30	384
SHUTTLE ONLY FLIGHTS																					
NASA	1	1	4	4	2	3	2	3	20	3	4	3	4	3	4	3	4	3	4	3	58
DoD				6	5	5	5	4	25	3	5	4	2	1	2	1	2	1	1	1	48
SUBTOTAL	1	1	4	10	7	8	7	7	45	6	9	7	6	4	6	4	6	4	5	4	106
TOTAL KSC FLIGHTS	2	4	6	27	23	24	21	34	141	29	33	29	33	30	31	23	33	35	40	33	489
VAFB																					
CIVIL				1	1	1	1	1	5	1	1	1	1	2	2	2	2	2	2	2	23
NASA				1	1	1	1	1	5	1	1	1	1	1	1	2	2	2	2	2	21
DoD				4	4	4	4	5	21	7	6	8	9	8	7	8	8	9	8	9	108
TOTAL VAFB FLIGHTS				6	6	6	6	7	31	9	8	10	11	11	10	12	12	13	12	13	152
TOTAL ALL FLIGHTS (KSC AND VAFB)	2	4	6	33	29	30	27	41	172	38	41	39	44	41	41	35	45	48	52	46	641

COMPARISON OF OPTIONS - 1990-2000

As indicated on the chart, Option A, the space program with SOC, appears to be the next desireable option. This option requires the least number of shuttle and OTV flights, with the greatest mass load factor (.96).

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COMPARISONS OF OPTIONS - 1990-2000

SOC OPTION BEST

	OPTIONS		
	A	C-1	C-2
NO. OF SUPPORT SYSTEM ITEMS SOC PAM-A PAM-D OTV DELTA ORBITER (≥4 FLEET)	 1 8 8 12 7	 — 8 8 172 10	 — 8 8 22 12
NO. OF MISSIONS	530	530	689
NO. OF OTV FLIGHTS	172	172	331
NO. OF STS FLIGHTS GEO NODE TOTAL (INCLUDES VAFB)	 *247 436	 366 548	 468 [illegible]
GEO NODE FLIGHTS MASS LOAD FACTOR	0.96	0.37	0.75

* INCLUDES HIGH DENSITY CARGO BAY PACKAGING TO REDUCE STS FLIGHT REQUIREMENT FROM 288

FLEET SIZE REQUIREMENTS

Contingency allowances need to be considered in the expression determining the fleet size. However at this time, this is an unknown factor. The influence of contingency considerations is indicated on the following chart.

FLEET SIZE REQUIREMENTS

FLEET SIZE DEPENDS UPON

- FLIGHT RATE
- MISSION DURATION
- TURNAROUND TIME

$$N = \frac{\text{(FLT RATE)} \times \text{(DURATION + TURNAROUND)}}{365}$$

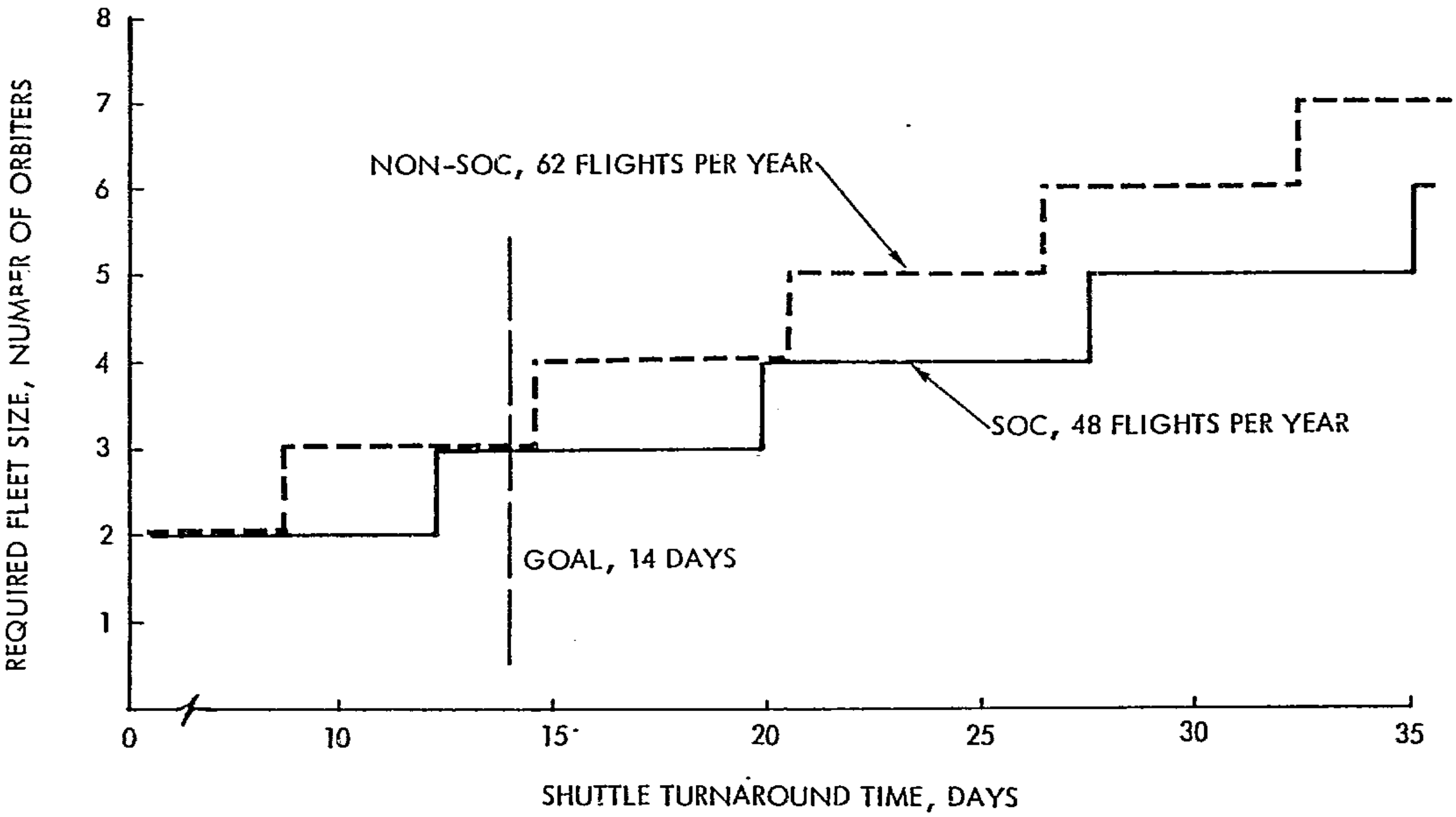
CONTINGENCY ALLOWANCE

- MATURE SYSTEM BY 1990
- WEATHER
- WTR - ETR SCHEDULES & TRANSFER TIME, IF REQUIRED
- LAUNCH PRIORITIES ISSUES
  - DOD VS CIVIL
  - COMMERCIAL VS NASA
- INVESTMENT IN FACILITIES VS ORBITERS

TURNAROUND TIME EFFECTS ON FLEET SIZE

This chart shows the effect of ground turnaround as the number of shuttles required for the 48 flights per year rate for the SOC option, and the 62 flights per year for the non-SOC option. A nominal 14 day turnaround indicates a 3 orbiter fleet size for both programs. However, no contingency capability is permitted with the three orbiter fleet for non-SOC options. Four orbiters are, therefore, required. The SOC option, however, indicates a significant margin is available with a 3 orbiter fleet.

TURNAROUND TIME EFFECTS ON FLEET SIZE



TRAFFIC SENSITIVITIES

This chart indicates the five traffic sensitivity areas analyzed. The number of shuttle flights can be reduced with the use of an increased performance shuttle with the capability to deliver 80K pounds of payload. Increase in OTV performance and the use of aerobraking can also reduce the number of shuttle flights. However, none of these benefits can be achieved unless the payload density can be significantly increased over the 2.5 lbs/ft^3 that our analysis has indicated is the average payload density.

Significant increases in the number of shuttle flights have previously been discussed if propellant scavenging is not implemented. Increased flights also are evident if the SOC would fly a constant altitude strategy rather than the variable altitude strategy.

TRAFFIC SENSITIVITIES

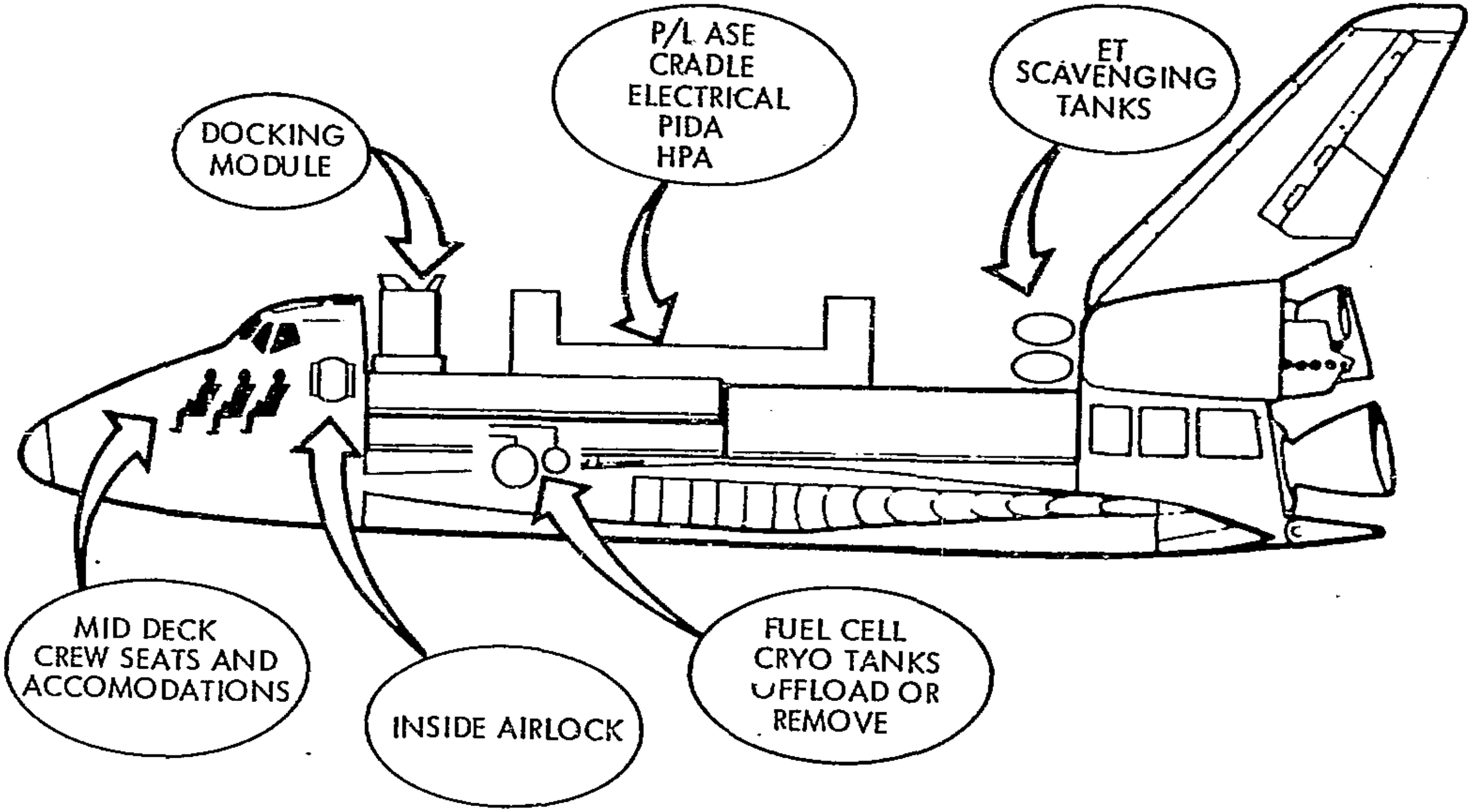
REFERENCE VALUES (11 YR TRAFFIC):
N = 247 FLIGHTS ρ_{AVG} = 2.5 lb/ft^3

FACTOR		ΔN SHUTTLE FLTS	ρ_{AVG} lb/ft^3
OTV PERFORMANCE:	$\Delta\lambda = -0.01$.	+35 +26	2.5 5.3
	$\Delta Isp = -10$ sec	+19 +14	2.5 5.4
STS P/L PERF: 80K ORBITER		0 -57	2.5 7.1
AEROBRAKING		0 -27	2.5 6.3
NO SCAVENGING	(a) 9000 lb/FLT (b) 3% LOAD FACTOR	+61 +12	-7% -1.3%
CONSTANT ALTITUDE STRATEGY		+52	3.5

DEDICATED ORBITER CONSIDERATIONS

The items that need to be considered in determining the desireability of providing an orbiter dedicated only to SOC operations is indicated on this chart.

DEDICATED ORBITER CONSIDERATIONS



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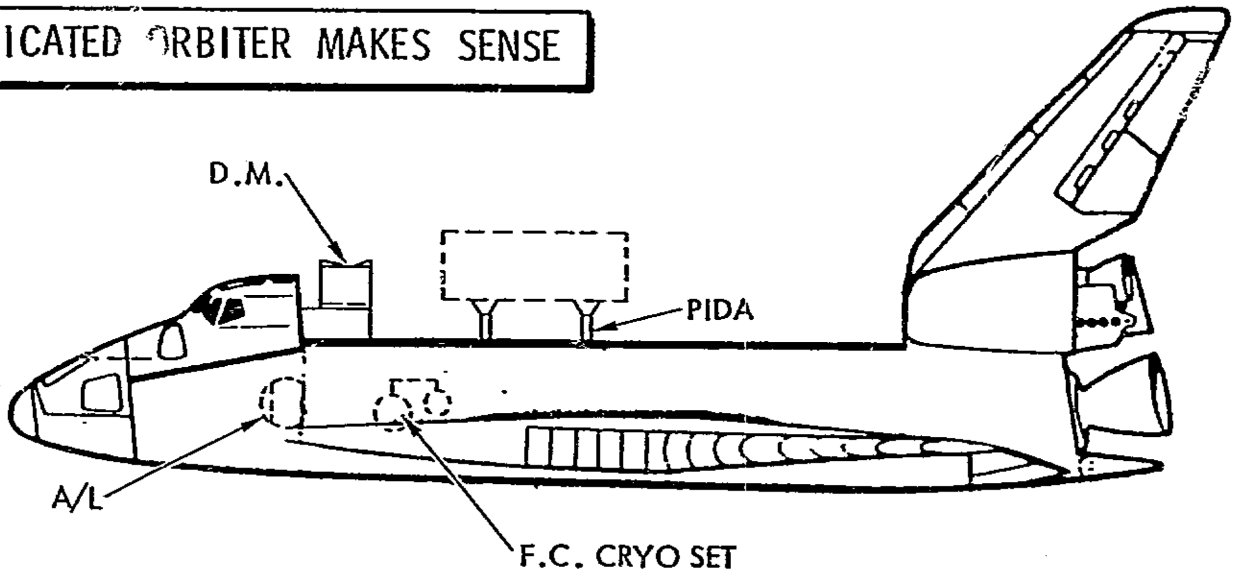
DEDICATED ORBITER BENEFITS SUMMARY

The dedicated orbiter configuration is indicated on this chart with the benefits that can be realized by this assignment. The costs are based on the 11-year period, 1990-2000.

DEDICATED ORBITER BENEFITS SUMMARY

A DEDICATED ORBITER MAKES SENSE



STD CONFIG
- DOCKING MODULE
- NO INSIDE AIRLOCK
- ELIM ONE F.C. CRYO SET
- DUAL PIDA
- 1/2 C & D

- SAVES UP TO $25\overline{M}$ IN TURNAROUND COSTS
- YIELDS OVER $650\overline{M}$ EXTRA PROPELLANT TO ORBIT

TASK 1.0 SUMMARY

SOC IS THE WAY TO GO

- SOC CAN SAVE OVER 200 SHUTTLE FLIGHTS OVER 20 YEAR SOC LIFE
  - APPROXIMATELY DOUBLES LOAD FACTOR
  - REDUCES FLIGHT RATE BY MORE THAN 20 PERCENT
  - REDUCES FLEET SIZE BY AT LEAST ONE "BIRD"
- GAINS IN OTV PERFORMANCE & SHUTTLE LIFT CAPABILITY OFFER FURTHER COST SAVINGS . . . . BUT ONLY IF P/L PACKAGED DENSITY IS INCREASED (BOTH SOC & NO SOC)
- VARIABLE ALTITUDE STRATEGY FOR SOC OFFERS SIGNIFICANT LOGISTICS BENEFITS
- A DEDICATED ORBITER MAKES SENSE

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CONCLUSIONS

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SPACE OPERATIONS PROGRAM

- DEDICATED ORBITER FOR SOC OPERATIONS
- PROPELLANT DELIVERY UTILIZING SCAVENGING TECHNIQUE
- REUSABLE SPACE BASED OTV
- PERFORM SATELLITE SERVICING & ASSEMBLY FROM SOC
- SOC FLY A VARIABLE ALTITUDE STRATEGY
- PROPELLANT STORAGE ON SOC WITH ACTIVE REFRIGERATION

SOC ASSEMBLY OPERATIONS

- ASSEMBLY PERFORMED BY ORBITER UTILIZING RMS, HPA & PIDA
- ASSEMBLY COMPLEXITY MINIMIZED WITH 40 FOOT LONG MODULES

ORBITER MATING OPERATIONS

- DOCKING & BERTHING CAPABILITY WITH SOFTWARE CHANGES

EXECUTIVE SUMMARY

SHUTTLE FLEET UTILIZATION & PROGRAMMATICS

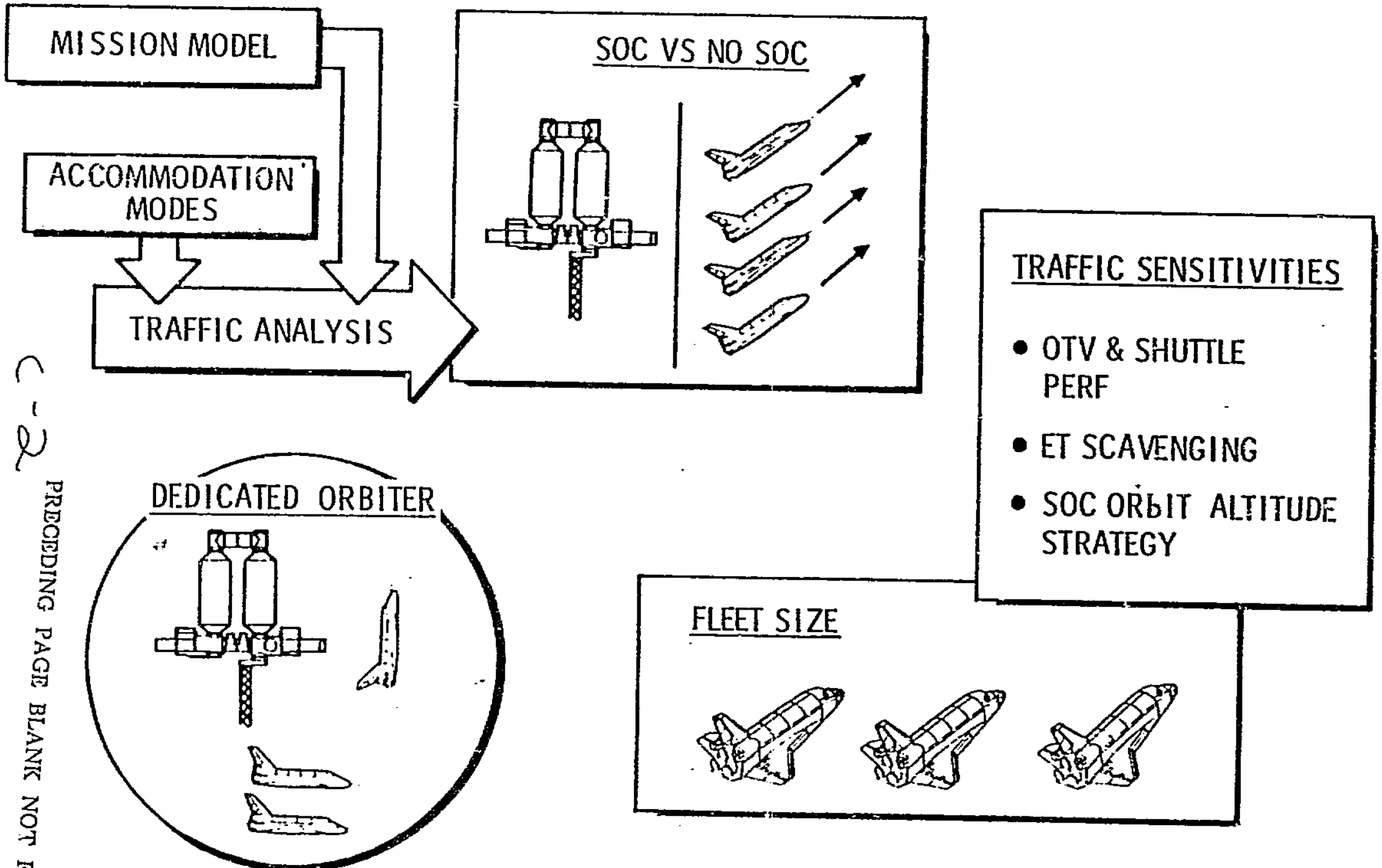
SOC ASSEMBLY OPERATIONS

FLIGHT SUPPORT FACILITY

SHUTTLE SYSTEM PROPELLANT SCAVENGING

CLOSING REMARKS

SHUTTLE FLEET UTILIZATION AND PROGRAMMATICS



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C-2

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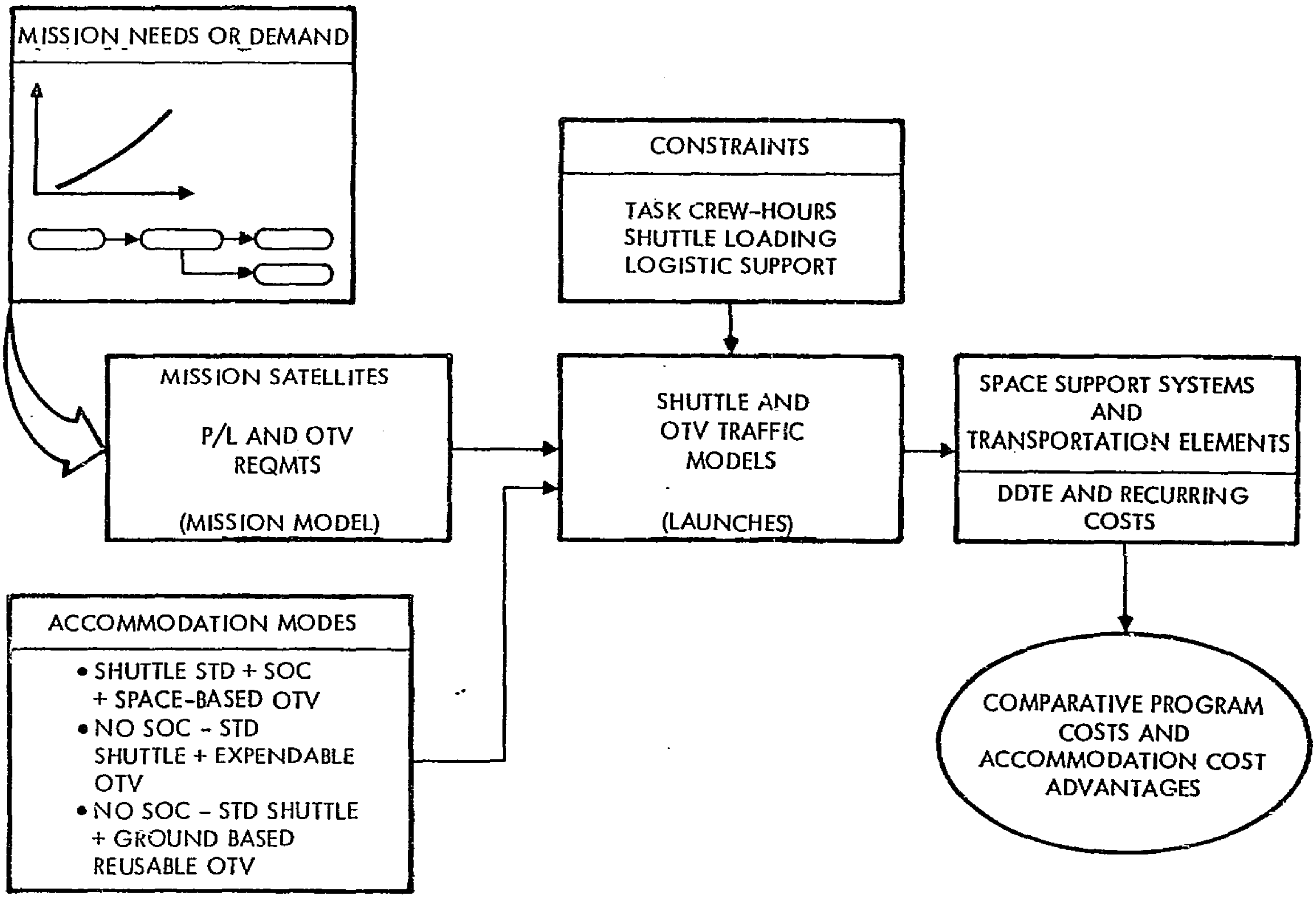
MISSION MODEL -- ACCOMMODATION TRADES



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MISSION SCENARIO DEFINITION

- MISSION MODEL DEFINITION ~ MEDIUM MODEL (LOW & HIGH MODELS IN WORK)
- ALL KSC & VAFB SHUTTLE MISSIONS IN THE 1982-2000 YEAR PERIOD
- MISSION REQUIREMENTS FOR THE FIRST 11 YEARS OF SOC OPERATIONS
  - BASIC MODULES & STRUCTURES
  - PROPELLANTS & TANKS
  - SOC LOGISTICS
- ORBITAL TRANSFER VEHICLES FOR GEO MISSIONS
- GEO NODE SPACECRAFT / SATELLITES
  - COMMUNICATIONS (U. S. COMMERCIAL & FOREIGN)
  - SPACE PROCESSING
  - SPACE CONSTRUCTION
  - SATELLITE SERVICING
  - NASA LIFE SCIENCES
  - DOD GEO NODE
  - NASA PLANETARY
  - NASA TECHNOLOGY DEVELOPMENT
- NASA CIVIL & DOD SHUTTLE FLIGHTS ~ KSC & VAFB

POTENTIAL MODEL DEFINITION AND USE CRITERIA

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HIGH-HIGH

- EVERYONE'S HOPE -- WHAT WE ARE NOT DESIGNING FOR?

HIGH MODEL

- REASONABLE PROBABILITY OF OCCURENCE -- DESIGN REQUIREMENTS
- ACCOMMODATION OF ALL MISSIONS -- NOT OPTIMUM -- LOW TRAFFIC MISSIONS

MEDIUM MODEL

- HIGH PROBABILITY OF OCCURENCE (66%)
- OPTIMUM DESIGN POINTS -- HIGHEST TRAFFIC MISSIONS
- ALTERNATIVE ACCOMMODATION OPTION STUDIES

LOW MODEL

- CERTAINTY IT WILL HAPPEN (99%)
- MINIMUM GROWTH IN MISSION P/L -- SIZE & NUMBER

ALTERNATE ACCOMMODATION MODES
OPTION DEFINITION

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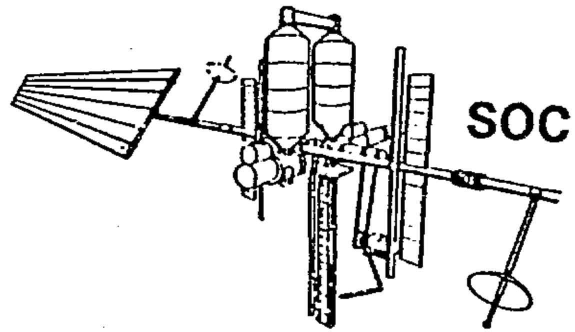
- **PRIME SYSTEM**

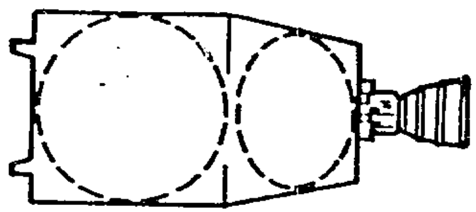


OPTION: A

- **OTV SYSTEM**

SPACE-DESIGN REUSABLE 12K TO GEO

- **OTV DESIGN CHARACTERISTICS**
  - $L = 30.2$ FT
  - $DIA = 14.5$ FT
  - $W_P = 48.4$ KLB
  - $W_{ST} = 53.4$ KLB



- **PROPELLANT SOURCES**
  - SHUTTLE TOP-OFF
  - EXTERNAL TANK TRANSFER
- **P/L C/O**
  - P/L - OTV MATING & C/O AT SOC

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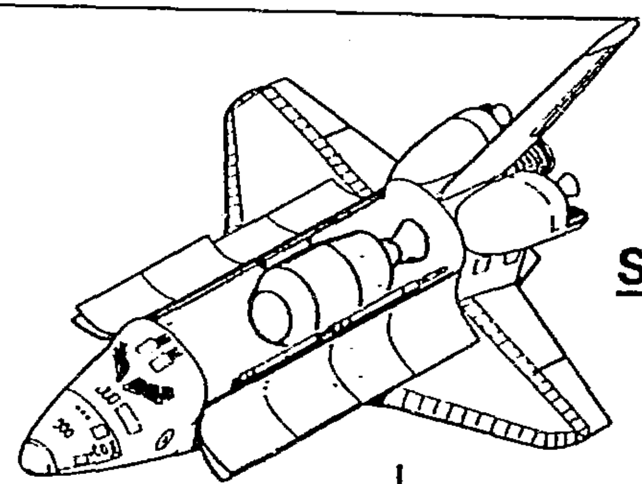
ALTERNATE ACCOMMODATION MODES (CONT)

- **PRIME SYSTEM**



SHUTTLE
- 4 MAN
- 10 DAY ORBITER

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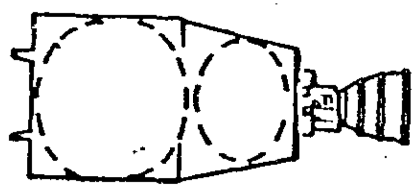
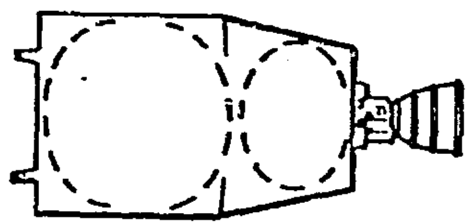
OPTION:

- **OTV SYSTEM**
  - (C-1) GROUND-DESIGN EXPENDABLE 12K TO GEO
  - (C-2) GROUND-DESIGN REUSABLE SINGLE-SHUTTLE FLIGHT 7K TO GEO

- **OTV DESIGN CHARACTERISTICS**



C-1: L = 24 FT, DIA = 13 FT, WP = 24.0 KLB, W_{ST} = 26.9 KLB



C-2: L = 28.3 FT, DIA = 14.5 FT, WP = 42.3 KLB, W_{ST} = 47.4 KLB

- **PROPELLANT SOURCES**
  - C-1: PROPELLANT DELIVERY WITH OTV
  - C-2: PROPELLANT DELIVERY WITH OTV

- **P/L C/O**
  - C-1: P/L C/O IN SHUTTLE
  - C-2: P/L C/O IN SHUTTLE

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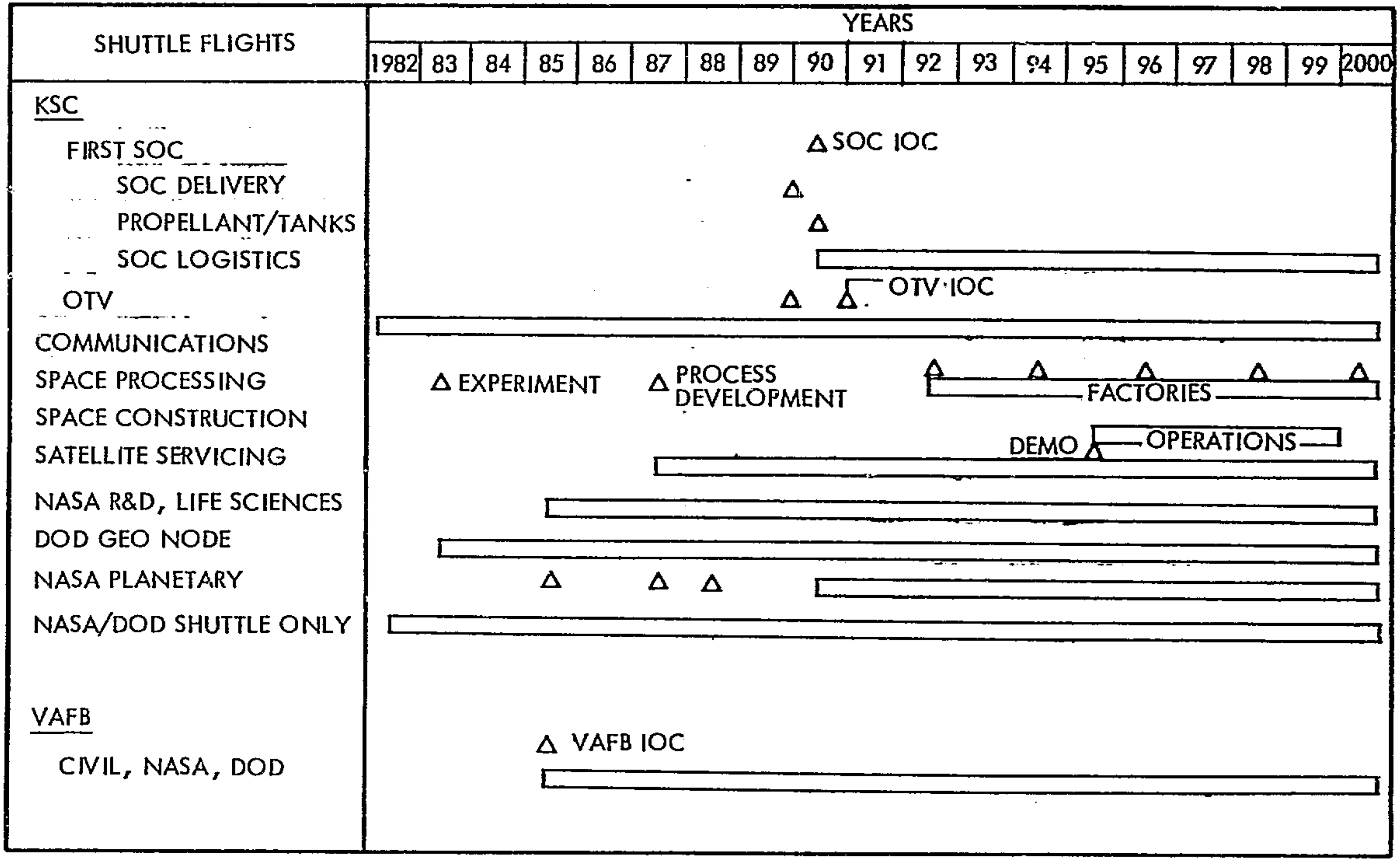
MISSION MODEL SCHEDULE



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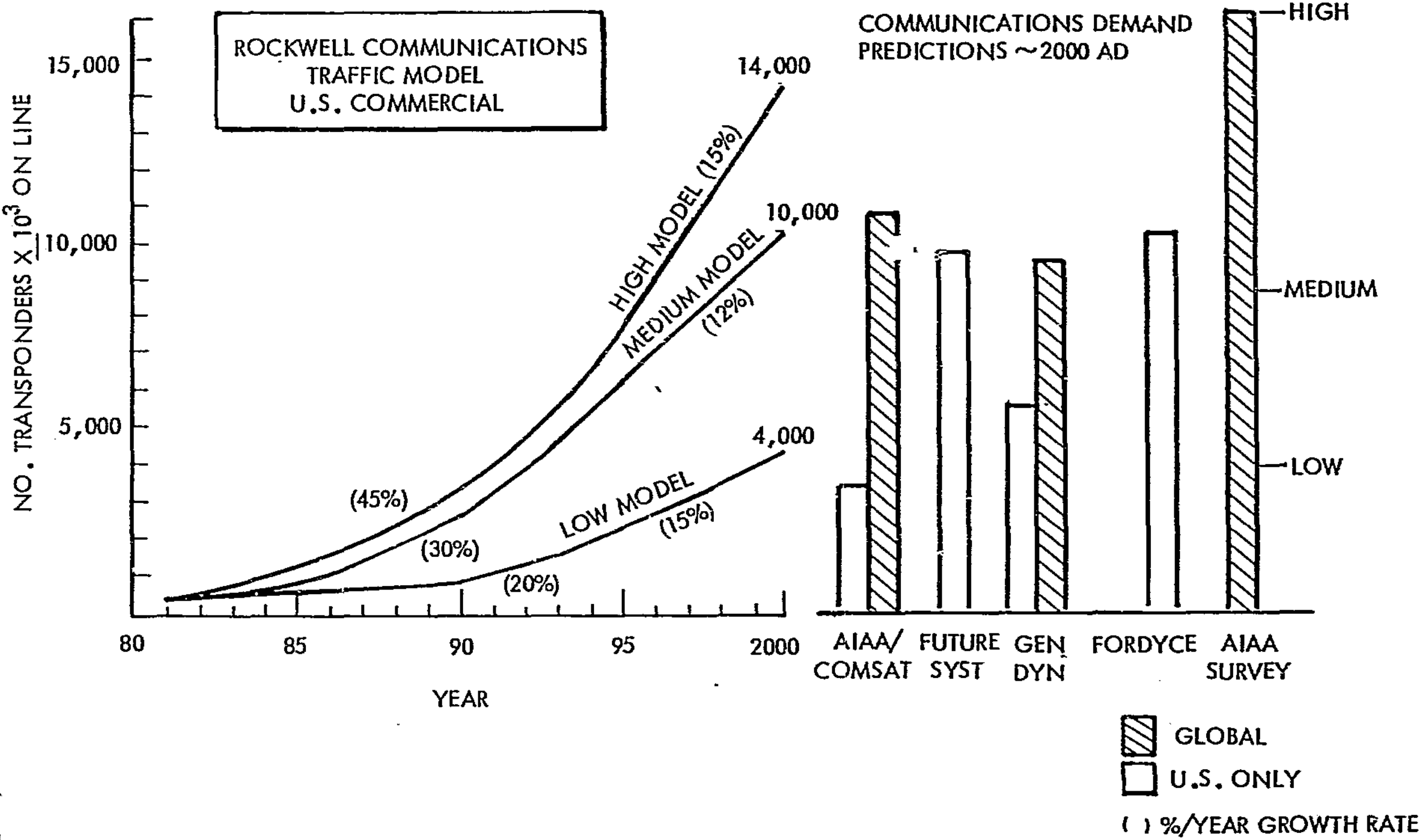
COMMUNICATION DEMAND PROJECTIONS



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CANDIDATE COMMERCIAL COMMUNICATIONS SPACECRAFT OPTIONS

TYPE	IOC	LIFE (YEAR)	WEIGHT (LB)	TRANSPONDERS		ORBITAL ARC SPACING	MAX. NO. SATELLITES IN ORBIT	MAX. NO. TRANSPONDERS/ SATELLITE TYPE
				TOTAL NO.	NO./BAND			
0	'81	5	1,000	24	12 C - 12 Ku	3°	24	576
I	'85	5	2,200	48	24 C - 24 Ku	3°	24	1,152
II	'85/'90	5/8	5,000	96	48 C + 48 Ku	3°	24	2,304
III	'90	8	13,000	240	24 C, 96 Ku, 120 Ka	3°	24	5,760
IV	'90	8	12,000	240	72 C, 66 Ku, 102 Ka	3°	24	5,760
V	'90	8	12,000	240	Ka ONLY	1°	72	17,280
VI	'90	8	6,000	80	Ka (+) OR Ka (-)	1°	144	11,520

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DOD MISSION MODEL

- USED AF PROVIDED SOURCE MATERIALS
- MADE REASONED ADAPTIONS TO ELIMINATE OBVIOUS DUPLICATIONS
- INCORPORATED ADJUSTMENTS CONSISTENT WITH EXISTENCE OF SPACE BASE/SOC
- BIBLIOGRAPHY:

SOURCE	APPLICATION
1. MILITARY SPACE SYSTEMS TECHNOLOGY MODEL VOL. II AEROSPACE REPORT NO. TOR-0081 (6909-40)-2, VOL. II	CURRENT AND FUTURE SPACECRAFT DESCRIPTIONS: MASS, VOLUME, CONSTELLATION SIZE, LOCATION
2. TRAFFIC MODEL FOR DOD UTILIZATION OF A SPACE PLATFORM AS81-01614	BASIS FOR FAR TERM SPACECRAFT LAUNCH RATES (1987-2000)
3. ADVANCED SPACECRAFT DEPLOYMENT SYSTEM STUDY AFRPL-TR-80-43 (BY MARTIN)	BASIS FOR NEAR TERM SPACECRAFT LAUNCH RATES (1985-1991), LOCATIONS & SOME MASS PROPERTIES
4. ENGINEERING JUDGMENT	SCHEDULES, GROWTH OPTIONS, ETC.

- RESULTING DOD MISSION MODEL IS "REPRESENTATIVE", NOT "OFFICIAL"
  IN AGGREGATE REFLECTS MASS & RATE SUFFICIENT FOR TRANSPORTATION REQUIREMENTS ANALYSIS

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MILITARY PAYLOAD GROWTH . . .

TRANSPORTATION NODE	1981 NUMBER MISSIONS	1981 MASS (LB)	MID-1990 NUMBER MISSIONS	MID-1990 MASS (LB)
GEO	5	3.5K LB	8	7.5K LB
LEO — MEDIUM INCLINATION				
MEDIUM ENERGY	2	3.5K LB	2	3.5K LB
HIGH ENERGY	2	4.0K LB	3	5.0K LB
HIGH INCLINATION (LOW ALTITUDE)	2	32.0K LB	6	35.0K LB
	11		19	

GROWTH POTENTIAL

MISSION EQUIPMENT GROWTH ~200 LB
- OPTICS
- ANTENNAS
- ELECTRONIC EQUIPMENT

COST AVOIDANCE ~700 LB
- HEAVIER STRUCTURE
- ENVIRONMENTAL PROTECTION
- DESIGN FOR SERVICING

SURVIVABILITY HARDWARE ~500 LB
- SHIELDING CIRCUMVENTION
- DECOYS

MISSION FLEXIBILITY & SURVIVABILITY ~2,000 LB
- MANEUVER PROPELLANT

NEW MISSIONS ~50,000 LB
- ASAT, DSAT
- SBR
- DS^3
- SBL

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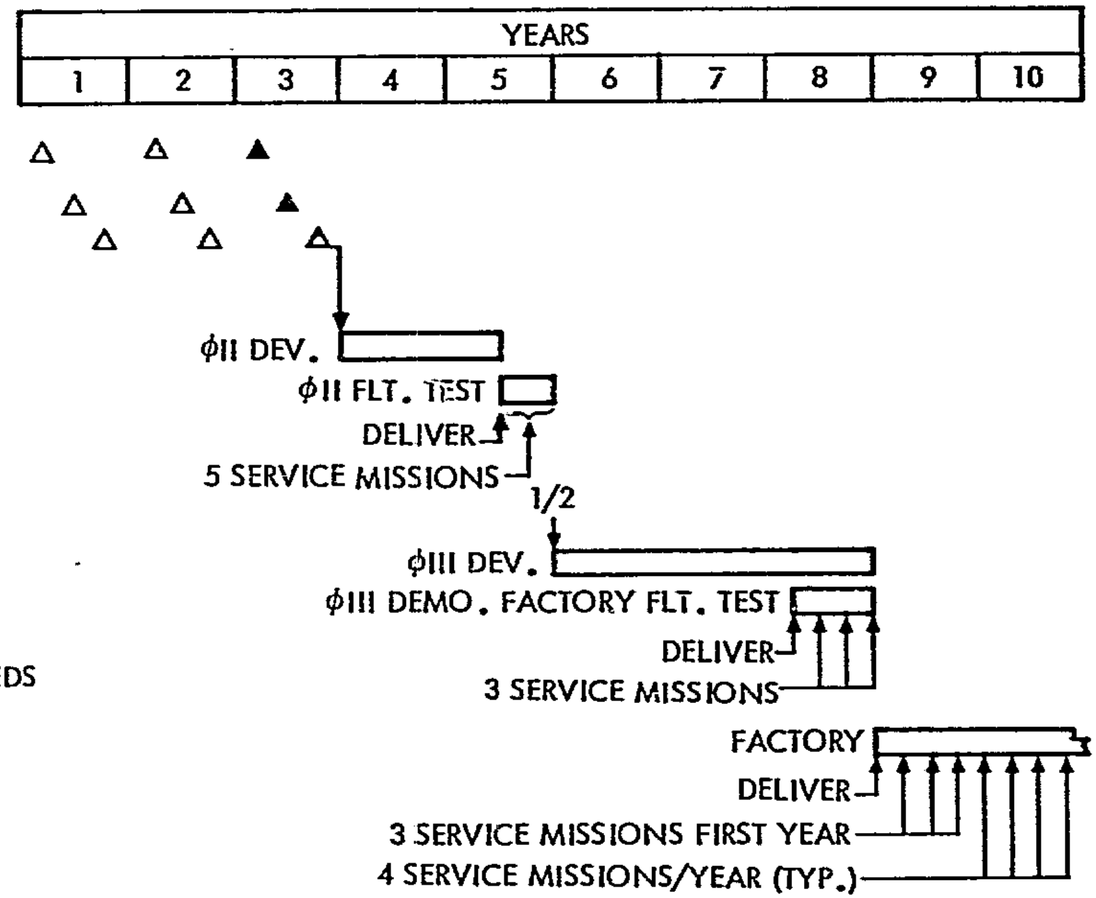
SPACE PROCESSING DEVELOPMENT LOGIC

- SPACE PROCESSING DEVELOPMENT LOGIC
  - THREE PHASE DEVELOPMENT

I	EXPERIMENTATION	~3 YEAR CYCLE
II	PROCESS DEVELOPMENT	~2 YEAR CYCLE
III	PRODUCTION DEVELOPMENT	~3 YEAR CYCLE – RESULTS IN FREE FLYING FACTORY

- MISSION FLOW (MEDIUM MODEL)



- φI – 3 EXPERIMENT STARTS PER YEAR
  - 1 MISSION PER YEAR PER EXPERIMENT START
  - 1 EXPERIMENT SUCCEEDS TO φII
- φII – 1-1/2 YEAR DEVELOPMENT
  - 1/2 YEAR FLIGHT TEST DELIVER TEST AND SERVICE MONTHLY
  - 50% φII DEVELOPMENTS SUCCEED TO φIII
- φIII – 3 YEAR DEVELOPMENT
  - DEMONSTRATION FREE FLYER IN 3RD YEAR WITH 3 SERVICES
  - EACH φIII DEVELOPMENT SUCCEEDS TO PRODUCTION FACTORY
- FREE FLYING PRODUCTION FACTORY
  - 4 SERVICE MISSIONS PER YEAR

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PAYLOAD MODEL
MISSION AREA ~ SPACE PROCESSING

	YEAR																			
	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000	TOTAL
1. PHASE I EXPERIMENT STARTS	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	57
2. PHASE I MISSIONS PER YEAR	3	6	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	162
3. PHASE 2 PROCESS DEVELOPMENT STARTS						1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
4. PHASE 2 SERVICE MISSIONS						5	5	5	5	5	5	5	5	5	5	5	5	5	5	70
5. PHASE 3 PRODUCTION DEVELOPMENT DEMONSTRATION (FREE FLYER)										1		1		1		1		1		5
6. PHASE 3 SERVICE MISSIONS										3		3		3		3		3		15
7. FACTORY NO. 1 (FREE FLY)											1									1
8. FACTORY NO. 1 SERVICE MISSIONS											3	4	4	4	4	4	4	4	4	35
9. FACTORY NO. 2													1							1
10. FACTORY NO. 2 SERVICE MISSIONS													3	4	4	4	4	4	4	27
11. FACTORY NO. 3															1					1
12. FACTORY NO. 3 SERVICE MISSIONS															3	4	4	4	4	19
13. FACTORY NO. 4																	1			1
14. FACTORY NO. 4 SERVICE MISSIONS																	3	4	4	11
15. FACTORY NO. 5																			1	1
16. FACTOR NO. 5 SERVICE MISSIONS																			3	3
TOTAL MISSION PAYLOADS (SUM LINES 2 THROUGH 16)	3	6	9	9	9	15	15	15	15	19	19	23	23	27	27	31	31	35	35	366

NASA R&D/LIFE SCIENCES PAYLOAD DEFINITION

MISSION NAME	ORBITER P/L PACKAGING			MISSION MODEL		
	P/L WT. (LB)	LENGTH (FT)	FRACTION OF P/L FLIGHT	LOW	MEDIUM	HIGH
SPAS-01 PALLET	4,000	15*	1/34	X	X	X
SPACE TELESCOPE	24,000	45	1	X	X	X
LDEF	9,900	29.85	1/2	X	X	X
SASP/25 kW POWER	49,000	44.0	1	X	X	X
OCEAN RESEARCH	4,300	15*	1/4	X	X	X
LARGE SOLAR OBSERVATORY	22,000	53.15	1		X	X
AMBIENT DEP. TELESCOPE	35,000	44.0*	1			X
IR INTERFEROMETER	49,000	32.8	3/4		X	X
EUVE—EXTRM EXP.	900	15	1/4			X
SCADM/SOL C & DYPL.	5,700	15*	1/4			X
LAMAR LARGE AREA MOD. ARRAY	11,500	20	1/3			X
GAMMA RAY TRANS. RES.	6,600	15*	1/4			X
GRO GAMMA	35,000	20	1/3		X	X
SOFT X-R SURVEY	3,500	15*	1/4			X
GRAV. SAT-A	3,500	4	1/4		X	X
NOAA	3,800	26	1/2			X
SIRTF	6,500	28	1/2			X
FIREX	19,000	15*	1/4			X
X-RAY SPECTROSCOPE	3,300	15*	1/4			X
OSTA	1,500	15*	1/4	X	X	X
SPACELAB	33,000	44.0*	1	X	X	X
LARGE DEPLOYABLE ANTENNA	10,300	15*	1/4			X
STARLAB TELESCOPE	4,400	15*	1/4			X
OAST	9,700	15*	1/4			X
COBE	3,100	15*	1/4			X
SL	30,000	44*	1			X
UARS	8,100	13	1/4	X	X	X
X-RAY ASTRO.	22,000	44*	1			X
GEOS G	1,600	15*	1/4			X
SOLAR POLAR	39,000	15	1/4			X

*ESTIMATED

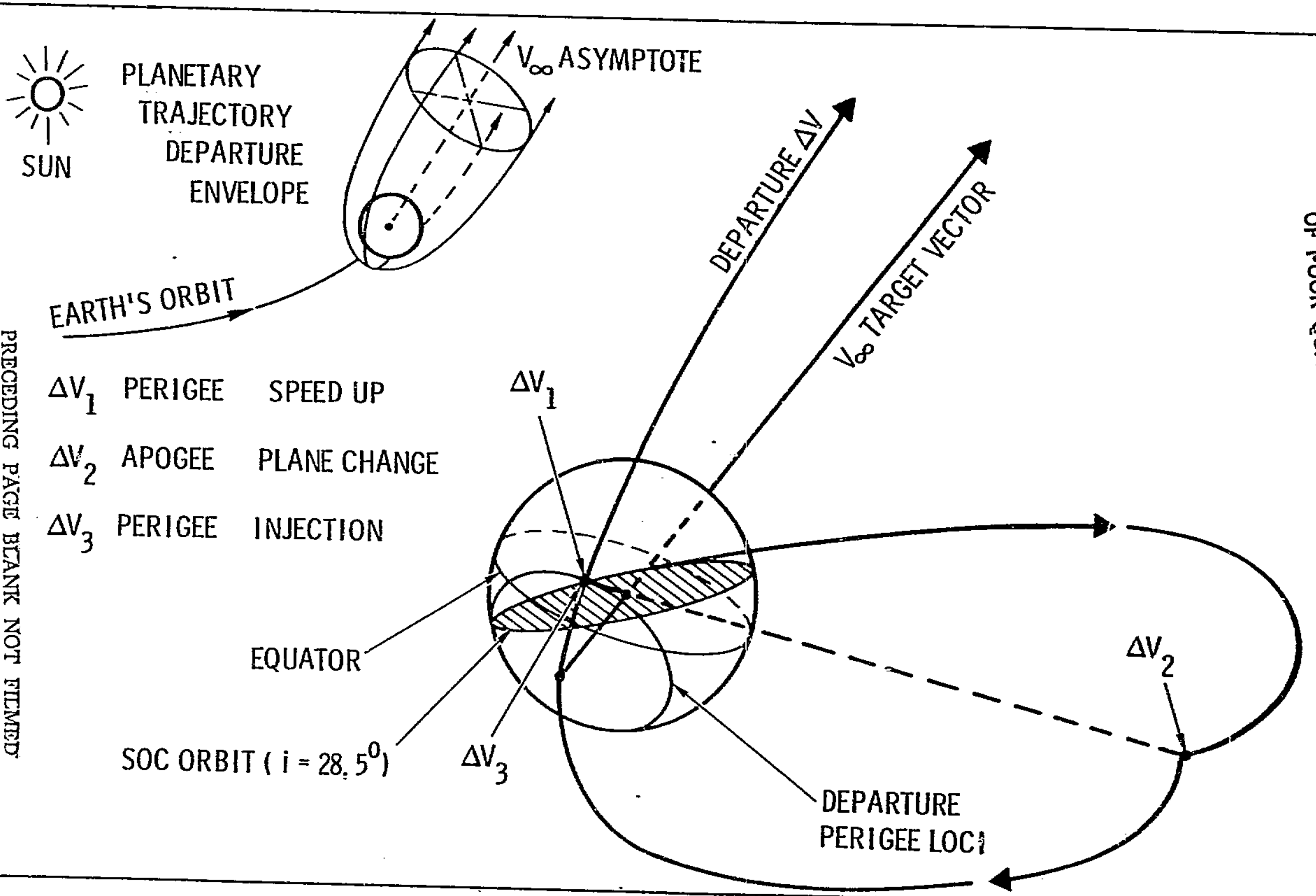
NASA PLANETARY MISSIONS, 1986-2000

YEAR	MISSION	MASS (LB)	LENGTH (FT)	LAUNCH VEHICLE	PROPELLANT (LB)**	MISSION MODEL*	ΔV (FT/SEC)
1986	GALILEO	5,500	15	CENTAUR		L M H	
1986	ISPM	2,000	10	IUS-2		L M H	
1988	VOIR	12,000	30	IUS-2		L M H	
1990	MARS GEOCHEMICAL ORBITER	5,300	13	OTV (RETURNS)	20,400	L M H	13,500
1991	APOLLO ASTEROID RENDEZ.	4,000	10	OTV	19,300	L M H	15,000
1992	LUNAR POLAR ORBITER	3,300	12	OTV	12,000	H	10,500
1993	SOLAR PROBE	3,000	15	OTV + LARGE TANKS	134,900	H	43,000
1994	URANUS PROBE	2,300	15	OTV + SMALL TANKS	74,020	M H	33,500
1995	MARS HYDROMETER ORBITER	5,300	13	OTV	20,400	M H	13,500
1996	COMET RENDEZVOUS	8,100	20	OTV + LARGE TANKS	122,500	M H	32,400
1997	MULTIPLE ASTEROID RENDEZ.	12,800	32	OTV + LARGE TANKS	127,800	M H	30,000
1998	SATURN ORBITER DUAL PROBE	11,200	30	OTV + LARGE TANKS	124,500	L M H	30,300
1999	VENUS PROBE	2,900	10	OTV	13,400	M H	12,500
2000	ASTROMETRY EARTH ORBITER	6,600	15	OTV	14,000	H	-8,000

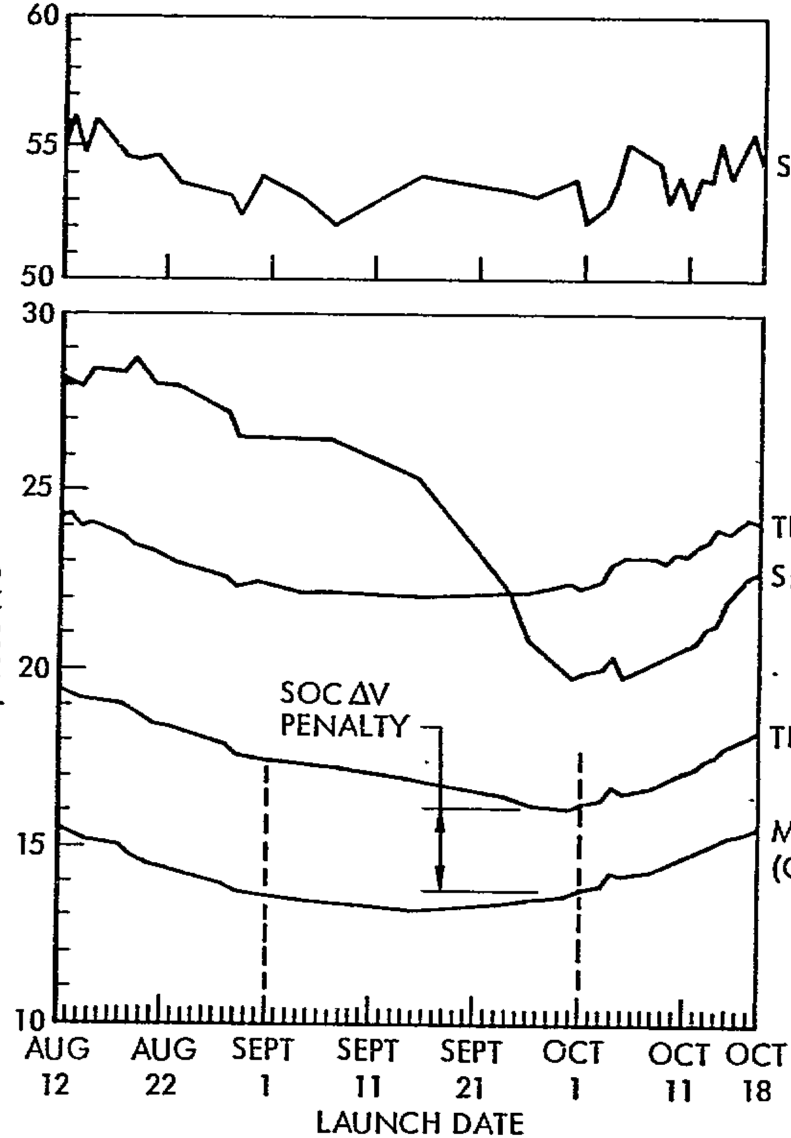
*L = LOW
M = MEDIUM
H = HIGH

**PROPELLANT REQUIREMENTS SHOWN
FOR SPACE DESIGN REUSATSLE OTV

3-IMPULSE PLANETARY INJECTION



PLANETARY ΔV REQUIREMENTS FROM SOC



MARS CLASS MISSION

PLANE CHANGE APOGEE AT GEO

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OF POOR QUALITY

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SATELLITE SERVICING MISSION MODEL - MEDIUM MODEL

MISSION	SERVICING WEIGHT (LB)	SERVICING SCHEDULE—YEAR													
		1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
• SPAS-01 PALLET	792			(D)		792	(D)		792		792			792	(D)
• SPACE TELESCOPE	4,890	4,890			(R)	(D)	4,840			(R)	(D)			4,840	
• LDEF	1,980	(D)			1,980	1,980	(D)		1,980		1,980	(D)			(D)
• SASP/25-kW POWER	17,600		(D)	8,000	17,600	17,600	17,600	(D)	17,600		17,600	17,600	(D)	17,600	17,600
• OCEAN RESEARCH	880								(D)		880	880		880	880
• LARGE SOLAR OBSERV.	4,312			(D)		4,312			4,312			4,312		4,312	4,312
• GRO GAMMA RAY OBSERV.	7,040						(D)		7,040		7,040	7,040			7,040
• IR INTERFEROMETER	9,900			(D)			9,900		9,900		9,900	9,900		9,900	9,900
• X-RAY TIME EXP.	316						(D)		316		316			316	316
• GOES-G				(D)		316	316		316		316	316		316	
• SPACELAB	6,600			(D)	(D)	6,600	(D)		6,600		6,600			6,600	6,600
• X-RAY OBSERV.	1,562			(D)		1,562	1,562				1,562	1,562		1,562	
• OSTA	299					(D)			(D)		299			(D)	299
TOTAL SERVICING WEIGHT/YEAR															

NOTE: (D) = DELIVERY/LAUNCH
(R) = RETRIEVAL

YEAR	MISSION NAME	MASS (LB)	REQUIRED UPPER STAGE	PROPELLANT (LB) A/C-I	MISSION MODEL			FINAL DESTINATION
1995	ORBITING DEEP SPACE RELAY STATION	9,500	OTV ONLY	44,400/20,000	LOW	MED	HIGH	GEO
1997	PIN-HOLE X-RAY TELESCOPE/ GRAVITY WAVE	36,300	OTV + 2 SMALL DROP TANKS	78,100/65,000		MED	HIGH	GEO
1999	SPS DEMONSTRATION	53,000	OTV + 2 LARGE DROP TANKS	109,200/95,300			HIGH	GEO

MISSION AREA PAYLOAD SUMMARY

• 1990-2000 STS FLIGHTS AND MISSION PAYLOADS TO GEO NODE	OPTIONS: A SOC + SPACE-BASED REUSABLE OTV	C-1 NO SOC EXPENDABLE OTV	C-2 NO SOC GROUND-BASED REUSABLE OTV
• STS FLIGHTS			
• TOTAL FLIGHTS	288	366	469
• 10 DAY MISSION FLIGHTS	0	279	437
• GEO NODE MISSION AREA S/C PAYLOADS			
• U.S. COMMERCIAL COMM	61	61	167
• FOREIGN COMMERCIAL COMM	31	31	84
• DoD PAYLOADS (GEO)	74	74	74
• NASA PLANETARY	12	12	12
• SPACE PROCESSING	285	285	285
• NASA R&D, LIFE SCIENCE	25	25	25
• SATELLITE SERVICING	40	40	40
• SPACE CONSTRUCTION	2	2	2
• TOTAL MISSION S/C PAYLOADS	530	530	689

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UPPER STAGE DEFINITION

UPPER STAGE	ORBITER CARGO BAY MANIFESTING				S/C P/L CAPABILITY TO GEO (lbs)
	STAGE WEIGHT (lbs)	ASE WEIGHT (lbs)	TOTAL PACKAGED WEIGHT (lbs)	PACKAGED LENGTH (ft)	
PAM-D	7,000	INC'L	7,000	7.2	1,400
PAM-A	13,000	INC'L	13,000	7.5	2,400
IUS	32,500	8,000	40,500	16.4	5,000
SPACE DESIGN REUSABLE OTV (OPTION A)	WET 53,400 DRY 5,000	1,400	DRY 6,400	30.2	12,000
GROUND DESIGN EXPENDABLE OTV (OPTION C-1)	WET 26,900 DRY 2,900	1,400	WET 28,300 DRY 4,300	24.0	12,000
GROUND DESIGN REUSABLE OTV (OPTION C-2)	WET 47,400 DRY 5,100	1,400	WET 48,800 DRY 6,500	28.3	7,000

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COMMERICAL COMMUNICATIONS SPACECRAFT SHUTTLE MANIFESTING DEFINITION

- S/C PACKAGED WITH UPPER STAGE (ASE WEIGHT INCLUDED WITH UPPER STAGE)

S/C TYPE	S/C WEIGHT (LB)	UPPER STAGE USED	CARGO BAY PACKAGING		
			S/C LENGTH (FT)	TOTAL LENGTH WITH UPPER STAGE (FT)	TOTAL WEIGHT WITH UPPER STAGE (LB)
0	1,000	PAM-D	15.0	15.0	8,000
I	2,200	PAM-A	22.5	30.0	15,200
II THROUGH 1989	5,000	IUS	26.6	43.0	45,500

- S/C PACKAGED SEPARATE FROM UPPER STAGE (OTV DEPENDENT ON ACCOMMODATION OPTION)

S/C TYPE	S/C WEIGHT (LB)	ASE WEIGHT (LB)	CARGO BAY PACKAGING	
			TOTAL LENGTH (FT)	TOTAL WEIGHT (LB)
II, 1990-2000	5,000	3,500	26.0	8,500
III	12,000	2,500	44.0	14,500
IV	12,000	2,500	44.0	14,500
V	12,000	2,500	26.0	14,500
VI	6,000	3,500	26.0	9,500

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MEDIUM MISSION MODEL SUMMARY
SOC INTERACTION 1990-2000

MISSION AREA	NO. OF P/L REQUIRED	TYPES OF P/L NO. REQD, CARGO BAY PACKAGING, & DESCRIPTION				TOTAL WEIGHT OF P/L DELIVERIES TO SOC (KLBS)
COMMERCIAL COMMUNICATION	92	34	26 FT	12 K – 240 T Ka BAND		1104
		58	44 FT	12 K – 240 T C, Ku, & Ka BANDS		
DOD GEO PAYLOADS	74	24	LOW ρ	3 – 7.5 K	12–30 FT	370
		33	MED ρ	3 – 7 K	10–22 FT	
		17	HI ρ	5 – 10 K	8–13 FT	
NASA PLANETARY	12	4	LOW ρ	1.2 – 7.7 K	6.5–16 FT	127
		8	HI ρ	24 – 19 K	3.3 – 22 FT	
SPACE PROCESSING	285	99	φ I EXPERIMENT	99 SMALL PACKAGES	– 1K EA	1466
		66	φ II PROCESS DEVELOPMENT	11 FLT TEST MISSIONS 55 SERVICE MISSIONS	– 2K EA – 1K EA	
		20	φ III PRODUCTION DEVELOPMENT	5 FREE FLY MISSIONS 15 SERVICE MISSIONS	– 10K EA – 6K EA	
		100	PRODUCTION FACTORY	5 FREE FLY FACTORIES 95 SERVICE MISSIONS	– 40 K EA – 10 K EA	
NASA R&D, LIFE SCIENCE	25	9	30 FT	30 K R&D LEO MISSIONS		622
		8	32 FT	32 K LIFE SCI MISSIONS		
		8	26 FT	12 K GROWTH – GEO S/C		
SATELLITE SERVICING	40	6	27 – 39 FT	26 – 39 K LOGISTICS FOR 40 SERVICING MISSIONS OF 7 S/C		155
SPACE CONSTRUCTION	2	1	49 FT	36.5 K PINHOLE X-RAY TELE		46
		1	13 FT	9.5 K DEEP SPACE RELAY STA		

OPTION A MISSION MANIFEST (TYPICAL)

PAYLOAD CATEGORY	MISS	OTV	MASS (LB)	LENGTH (FT)	SHUTTLE FLIGHT NO.	CARGO MANIFEST (CODE: WEIGHT (K LB) / LENGTH (FT))
SOC						
SOC LOGISTICS	4	0	35,000	26	1 – 4	DM 4.5/7; LOG MOD 35/26; UNUSED 18/18; ET 2.5/9
OTV						
OTV DELIVERY NO. 2	1	0	5,020	25	5	DM 4.5/7; OTV 5/25; UNUSED 48/19; ET 2.5/9
TELEOPERATOR	1	0	11,000	20	6	DM 4.5/7; TELE 11/20; UNUSED 42/24; ET 2.5/9
COMMUNICATIONS						
US COMMERCIAL TYPE IV S/C	5	5	12,000	44	7 – 11	DM 4.5/7; S/C 12/44; ET 2.5/9
TYPE V S/C	1	1	12,000	26	12	DM 4.5/7; S/C 12/26; UNUSED 41/18; ET 2.5/9
FOREIGN TYPE IV S/C	2	2	12,000	44		
TYPE V S/C	1	1				
DOD						

- 11 YEARS OPERATIONS
- ALL MISSIONS AREAS
- PAYLOAD PHYSICAL CHARACTERISTICS AND MANIFESTING GROUNDRULES USED TO ESTABLISH 3 TRAFFIC MODELS
- UNALLOCATED LOAD FACTOR (LF) AND PAYLOAD VOLUME USED IN PROPELLANT TRANSPORT ANALYSIS (A)

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TOTAL TRAFFIC MODEL - ALTERNATE A

	YEAR																				
	82	83	84	85	86	87	88	89	SUM	90	91	92	93	94	95	96	97	98	99	00	SUM
KSC																					
FIRST SOC																					
SOC DELIVERY AND CHECK OUT								5	5												5
PROP STORAGE TANK DEL								2	2												2
SOC LOGISTICS								2	2	4	4	4	4	4	4	4	4	4	4	4	46
OTV TEST								1	1												1
OTV DELIVERY										2	2	2	2	2	2	1	2	3	2	2	22
25 KW MODULE						1		1	2												2
TELEOPERATOR										1											1
SUBTOTAL						1		11	12	7	6	6	6	6	6	5	6	7	6	6	79
COMMUNICATIONS																					
US COMMERCIAL	1	1	1	5	5	6	5	3	27	6	6	5	5	5	5	2	3	9	10	5	88
FOREIGN (50%)		1		3	3	3	2	2	14	3	3	2	3	2	3	1	1	5	5	3	45
SUBTOTAL	1	2	1	8	8	9	7	5	41	9	9	7	8	7	8	3	4	14	15	8	133
DoD PAYLOADS				5	2	1	3	5	16	3	7	5	5	5	3	3	6	3	4	4	64
NASA PLANETARY				1	3	1		1	6				3	3	2		3		1		18
SPACE PROCESSING		1	1	1	1	2	2	2	10	1	1	2	2	3	3	4	4	5	5	6	46
NASA R&D, LIFE SCIENCE				1	1	1	1	1	5	2	1	2	2	2	2	3	2	2	3	4	30
SATELLITE SERVICING				1	1	1	1	2	6	1			1			1			1	2	12
SPACE CONSTRUCTION															1		2				3
SUBTOTAL		1	1	9	8	6	7	11	43	7	9	9	13	13	11	11	17	10	14	16	172
TOTAL KSC FLIGHTS TO GEO NODE	1	3	2	17	16	16	14	29	96	23	24	22	27	26	25	19	27	31	35	30	384
SHUTTLE ONLY FLIGHTS																					
NASA	1	1	4	4	2	3	2	3	20	3	4	3	4	3	4	3	4	3	4	3	58
DoD				6	5	5	5	4	25	3	5	4	2	1	2	1	2	1	1	1	48
SUBTOTAL	1	1	4	10	7	8	7	7	45	6	9	7	6	4	6	4	6	4	5	4	106
TOTAL KSC FLIGHTS	2	4	6	27	23	24	21	34	141	29	33	29	33	30	31	23	33	35	40	33	489
VAFB																					
CIVIL				1	1	1	1	1	5	1	1	1	1	2	2	2	2	2	2	2	23
NASA				1	1	1	1	1	5	1	1	1	1	1	1	2	2	2	2	2	21
DoD				4	4	4	4	5	21	7	6	8	9	8	7	8	8	9	8	9	108
TOTAL VAFB FLIGHTS				6	6	6	6	7	31	9	8	10	11	11	10	12	12	13	12	13	152
TOTAL ALL FLIGHTS (KSC AND VAFB)	2	4	6	33	29	30	27	41	172	38	41	39	44	41	41	35	45	48	52	46	641

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SOC-GEO NODE TRAFFIC MODEL - ALTERNATE A

	YEAR																				
	82	83	84	85	86	87	88	89	SUM	90	91	92	93	94	95	96	97	98	99	00	SUM
KSC																					
FIRST SOC																					
SOC DELIVERY AND CHECK OUT																					
PROP STORAGE TANK DEL																					
SOC LOGISTICS										4	4	4	4	4	4	4	4	4	4	4	44
OTV TEST																					
OTV DELIVERY										2	2	2	2	2	2	1	2	3	2	2	22
25 KW MODULE																					
TELEOPERATOR										1											1
SUBTOTAL										7	6	6	6	6	6	5	6	7	6	6	67
COMMUNICATIONS																					
US COMMERCIAL										6	6	5	5	5	5	2	3	9	10	5	61
FOREIGN (50%)										3	3	2	3	2	3	1	1	5	5	3	31
SUBTOTAL										9	9	7	8	7	8	3	4	14	15	8	92
DoD PAYLOADS										3	7	5	5	5	3	3	6	3	4	4	48
NASA PLANETARY													3	3	2		3		1		12
SPACE PROCESSING										1	1	2	2	3	3	4	4	5	5	6	36
NASA R&D, LIFE SCIENCE										2	1	2	2	2	2	3	2	2	3	4	25
SATELLITE SERVICING										1			1			1			1	2	6
SPACE CONSTRUCTION															1		2				3
SUBTOTAL										7	9	9	13	13	11	11	17	10	14	16	130
TOTAL KSC FLIGHTS TO GEO NODE										23	24	22	27	26	25	19	27	31	35	30	268

GEO NODE TRAFFIC MODEL - ALTERNATE C-1

	YEAR																				
	82	83	84	85	86	87	88	89	SUM	90	91	92	93	94	95	96	97	98	99	00	SUM
KSC																					
COMMUNICATIONS																					
US COMMERCIAL										11	11	9	9	9	7	2	3	14	15	9	99
FOREIGN (50%)										6	5	4	5	4	4	1	1	8	7	4	49
SUBTOTAL										17	16	13	14	13	11	3	4	22	22	13	148
DoD PAYLOADS										4	10	8	6	8	6	6	9	5	5	7	74
NASA PLANETARY													3	3	2		3		1		12
SPACE PROCESSING										2	3	4	5	5	6	7	8	8	10	10	68
NASA R&D, LIFE SCIENCE										2	1	3	2	3	3	5	4	4	5	5	37
SATELLITE SERVICING										2	2	2	2	2	2	2	2	2	2	2	22
SPACE CONSTRUCTION															2		3				5
SUBTOTAL										10	16	17	18	21	21	20	29	19	23	24	218
TOTAL KSC FLIGHTS TO GEO NODE										27	32	30	32	34	32	23	33	41	45	37	366

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GEO NODE TRAFFIC MODEL - ALTERNATE C-2

	YEAR																			
	82	83	84	85	86	87	88	89	SUM	90	91	92	93	94	95	96	97	98	99	00	SUM
KSC																					
COMMUNICATIONS																					
US COMMERCIAL										10	17	18	14	12	8	10	9	21	30	18	167
FOREIGN (50%)										5	8	9	7	6	4	5	5	10	15	9	83
SUBTOTAL										15	25	27	21	18	12	15	14	31	45	27	250
DoD GEO NODE										4	10	8	6	8	6	6	9	5	5	7	74
NASA PLANETARY													3	3	2		3		1		12
SPACE PROCESSING										2	3	4	5	5	6	7	8	8	10	10	68
NASA R&D, LIFE SCIENCE										2	1	3	2	3	3	5	4	4	5	5	37
SATELLITE SERVICING										2	2	2	2	2	2	2	2	2	2	2	22
SPACE CONSTRUCTION															2		3				5
SUBTOTAL										10	16	17	18	21	21	20	29	19	23	24	218
TOTAL KSC FLIGHTS TO GEO NODE										25	41	44	39	39	33	35	43	50	68	51	468

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COMPARISONS OF OPTIONS - 1990-2000

SOC OPTION BEST

	OPTIONS		
	A	C-1	C-2
NO. OF SUPPORT SYSTEM ITEMS			
SOC	1	—	—
PAM-A	8	8	8
PAM-D	8	8	8
OTV	12	172	22
DELTA ORBITER (⩾4 FLEET)	7	10	12
NO. OF MISSIONS	530	530	689
NO. OF OTV FLIGHTS	172	172	331
NO. OF STS FLIGHTS			
GEO NODE	*247	366	468
TOTAL (INCLUDES VAFB)	436	548	651
GEO NODE FLIGHTS MASS LOAD FACTOR	0.96	0.37	0.75

* INCLUDES HIGH DENSITY CARGO BAY PACKAGING TO REDUCE STS FLIGHT REQUIREMENT FROM 288

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AVERAGE CARGO CHARACTERISTICS
(11 YEAR TRAFFIC SUMMARY)

SOC		NON-SOC	
ΣN	= 247 STS FLIGHTS	ΣN	= 366 STS FLIGHTS
ΣW_{CARGO}	= 6,733,000 lb	ΣW_{CARGO}	= 3,974,000 lb
$\Sigma W_{PROPELLANT}$	= 7,485,000 lb	$\Sigma W_{PROPELLANT}$	= 4,128,000 lb
W_P REQUIRED	= 7,356,000 lb	W_P REQUIRED	= 4,128,000 lb
$\frac{W_P}{W_{CARGO}}$	= 1.093 lb/lb	$\frac{W_P}{W_{CARGO}}$	= 1.039 lb/lb
$\Sigma W_{P/L}$	= 4,557,000 lb	$\Sigma W_{P/L}$	= 3,017,000 lb
$(W_{P/L})_{AVG}$	= 18,450 lb	$(W_{P/L})_{AVG}$	= 8,240 lb
(W_{CARGO}) AVG	= 27,260 lb	(W_{CARGO}) AVG	= 10,860 lb
$(W_{CARGO}+W_P)$ AVG	= 57,560 lb	$(W_{CARGO}+W_P)$ AVG	= 22,140 lb
$(\rho_{P/L})$ AVG	= 2.5 lb/ft^3	$(\rho_{P/L})$ AVG	= 1.0 lb/ft^3
LOAD FACTOR:		LOAD FACTOR:	
60K REF $(L.F.)_{AVG}$	= 0.96	$(L.F.)_{AVG}$	= 0.37
56K REF $(L.F.)_{AVG}$	= 1.03		

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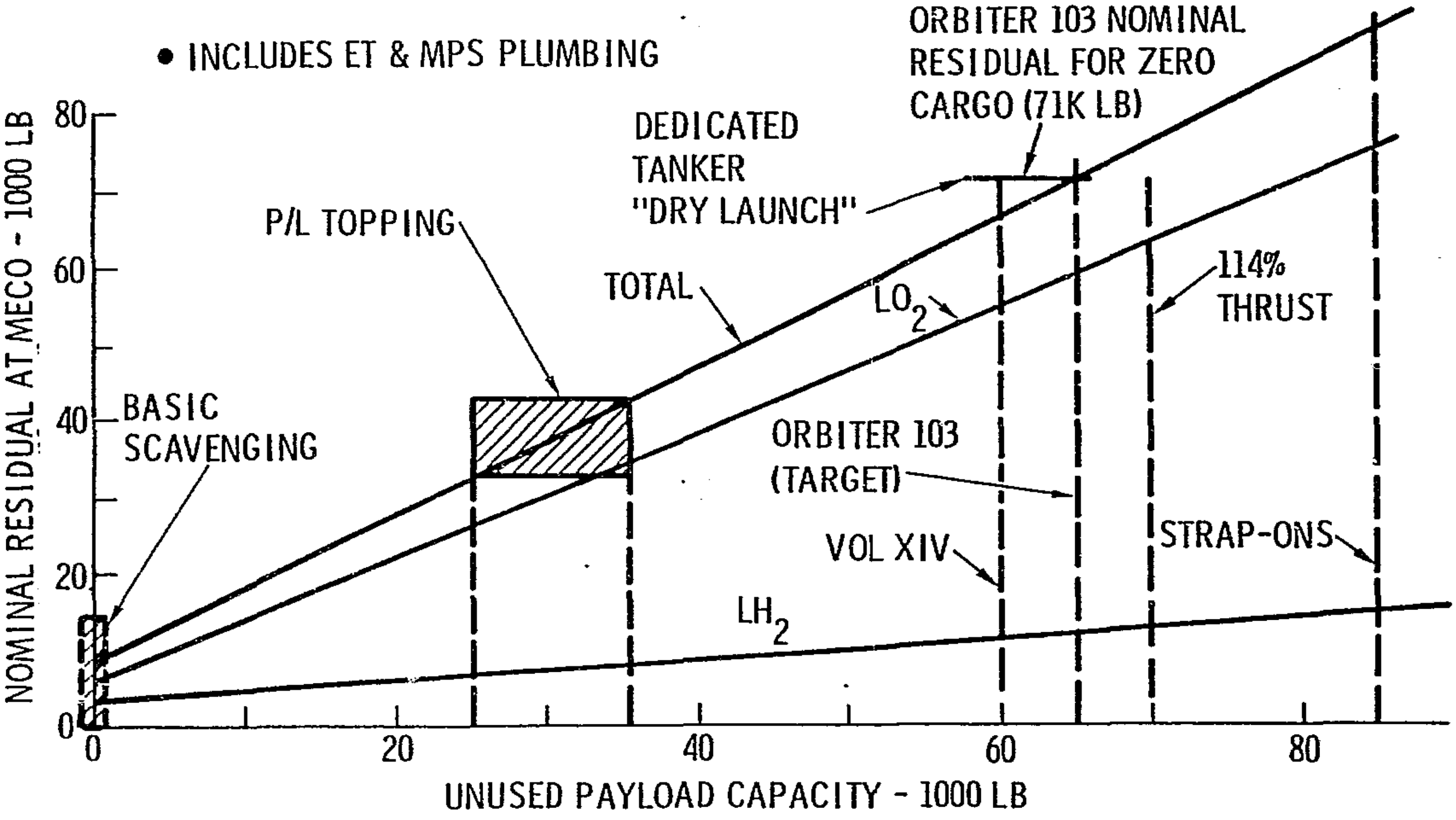
NOMINAL PROPELLANT RESIDUALS AT MECO



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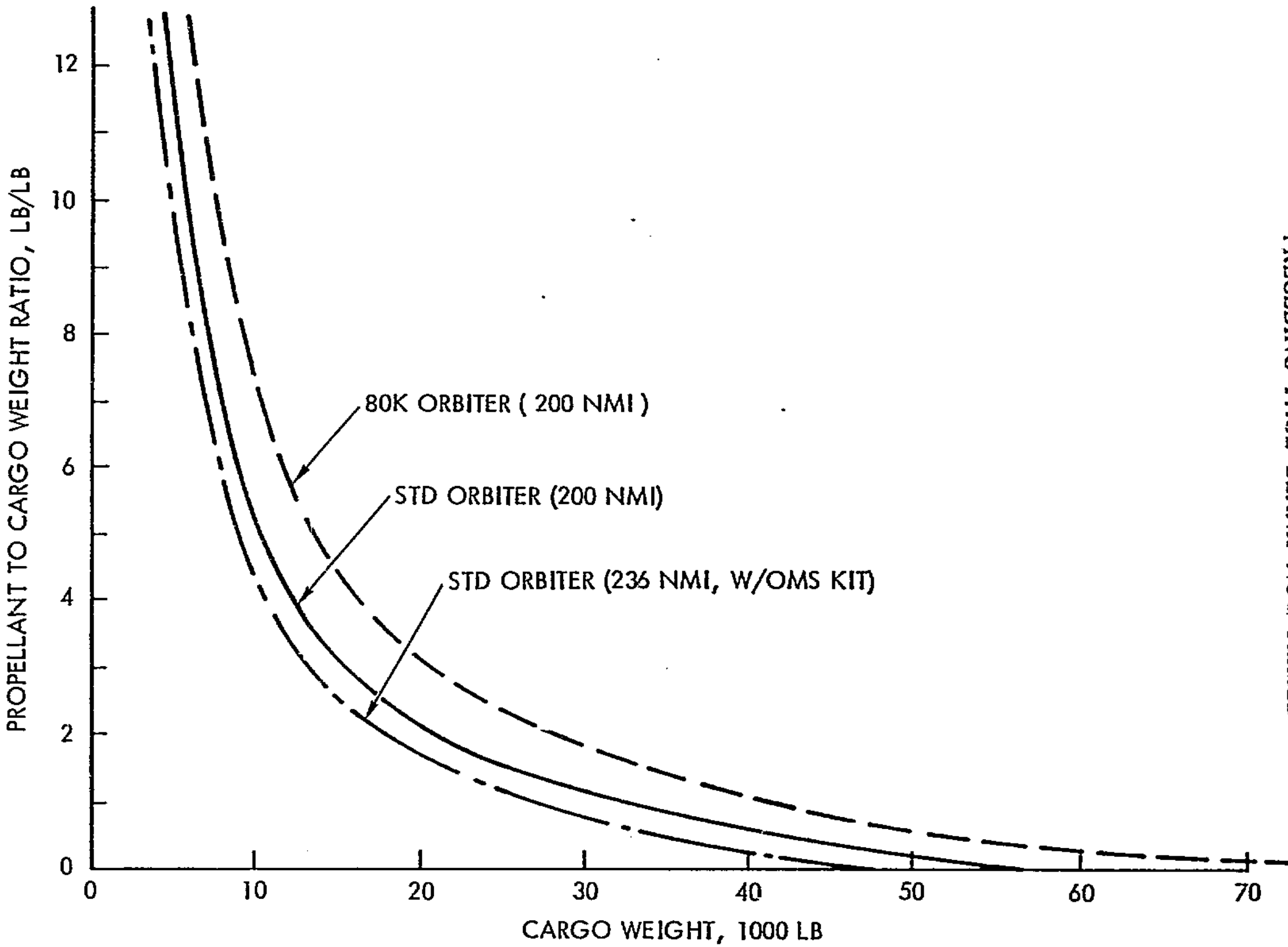
CARGO TO PROPELLANT WEIGHT RATIO FOR MAXIMUM SCAVENGING



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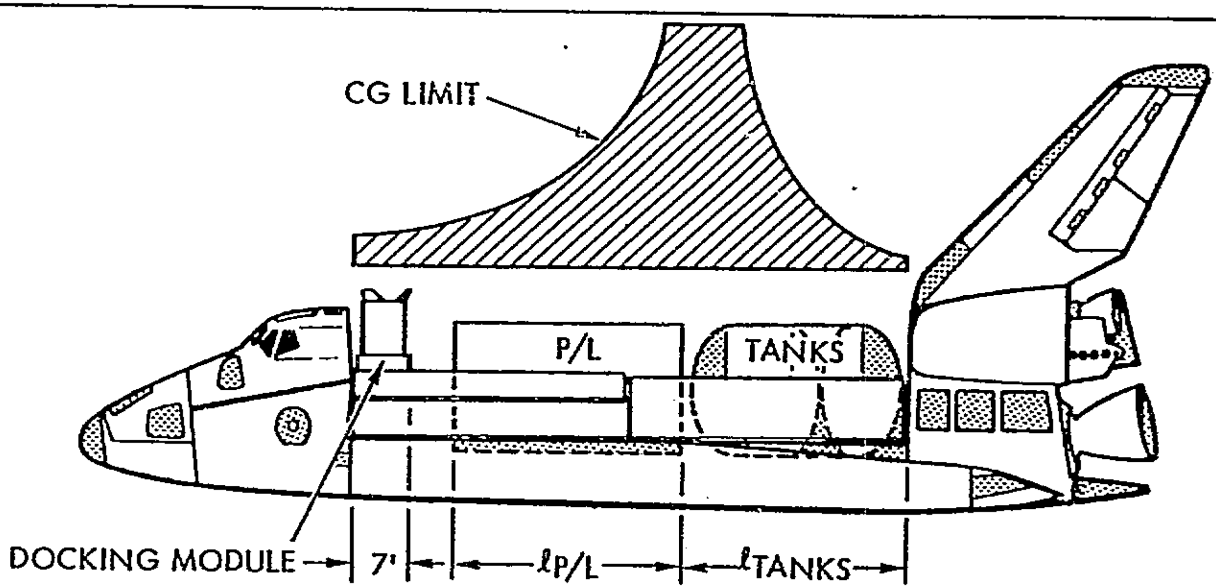
C.G. CONSTRAINTS ON PAYLOAD DENSITY



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WITH MAX SCAVENGING:

PROPELLANT, $W_p = f$ (UNUSED ORBITER P/L CAPABILITY)

$\ell_{TANK} = k_1 + k_2 W_p$

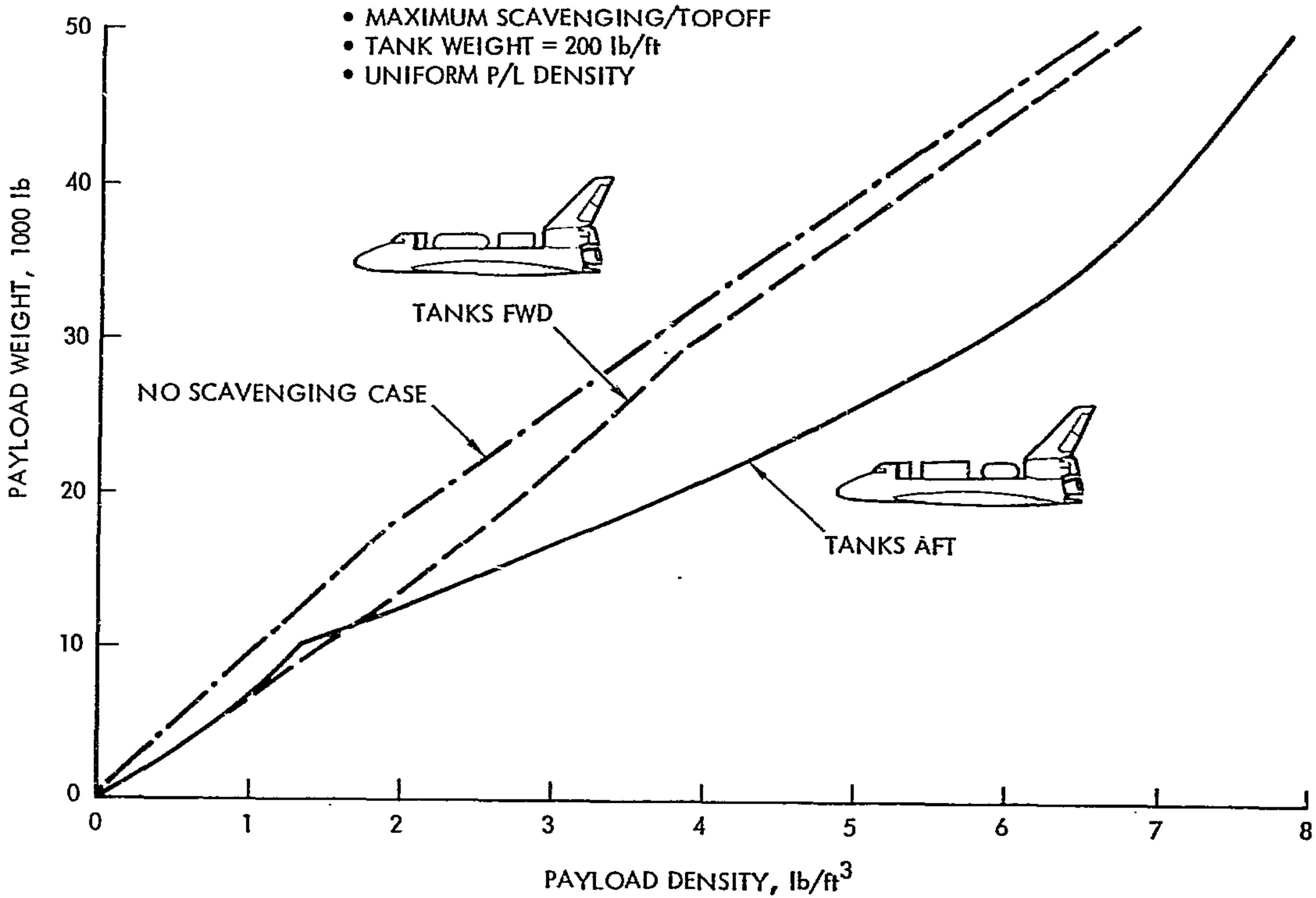
$$\text{C.G. LIMIT} = \frac{W_{DM} \times 56.5 + W_{P/L}\left(\ell_T + \frac{\ell_{P/L}}{2}\right)}{W_{DM} + W_{P/L}}$$

SOLVE FOR $\frac{\ell_{P/L}}{2}$

PAYLOAD DENSITY $\rho_{P/L} = \frac{W_{P/L}}{\ell_{P/L} \times 177}$, LB/FT^3

MINIMUM DENSITY FOR MAX LOAD FACTOR

ORBITER C.G. EFFECTS ON PACKAGED DENSITY



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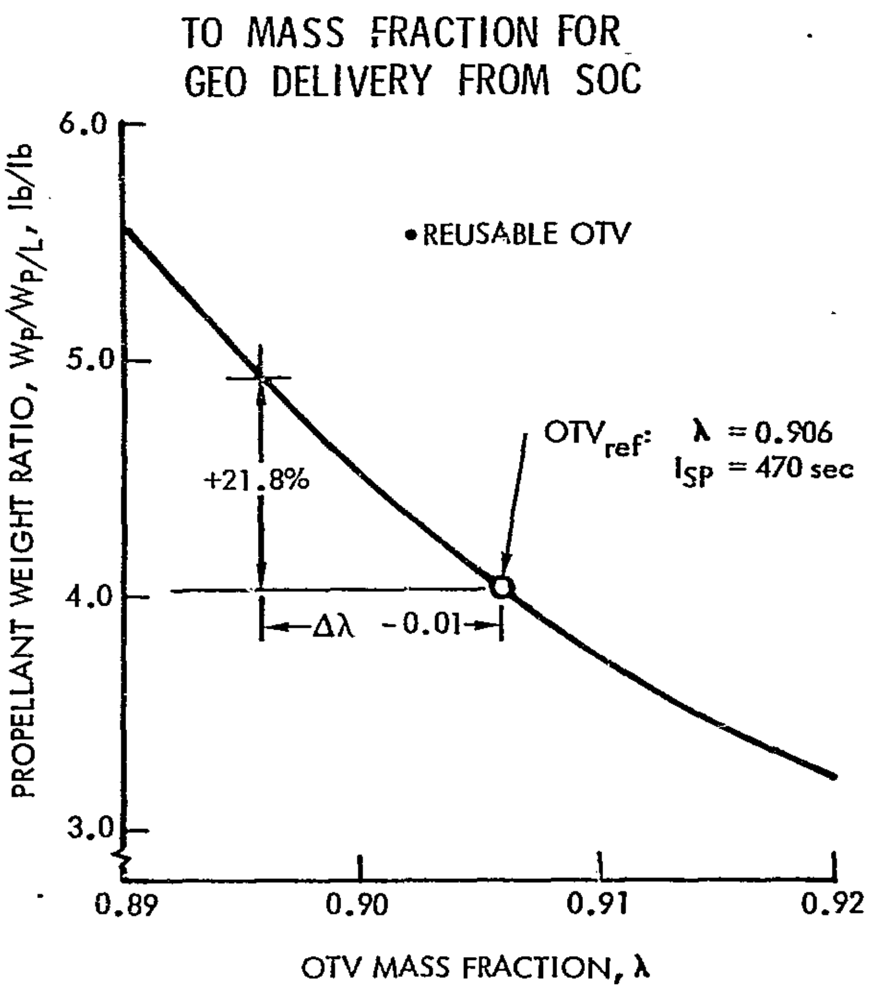
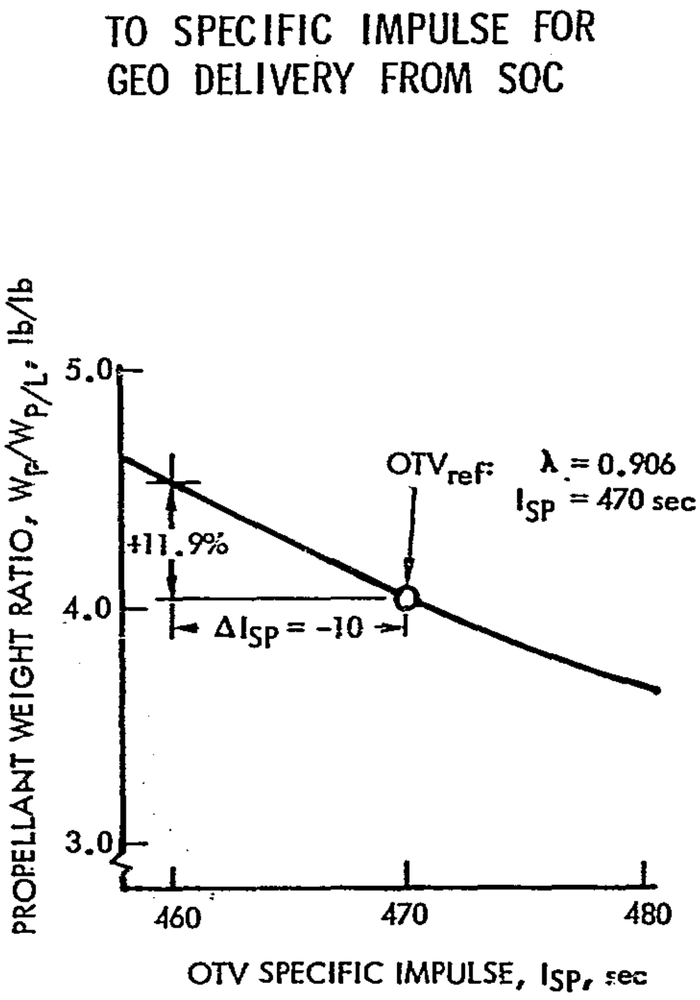
OTV PROPELLANT SENSITIVITY





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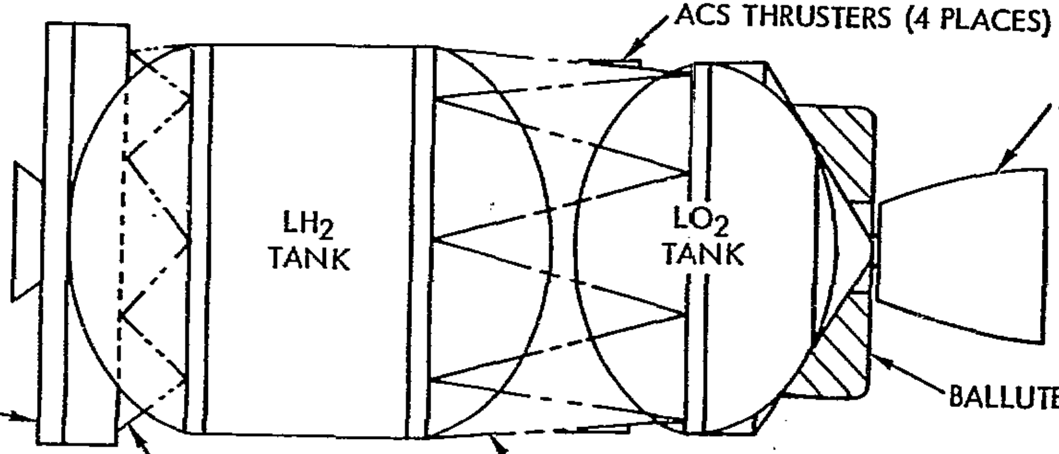
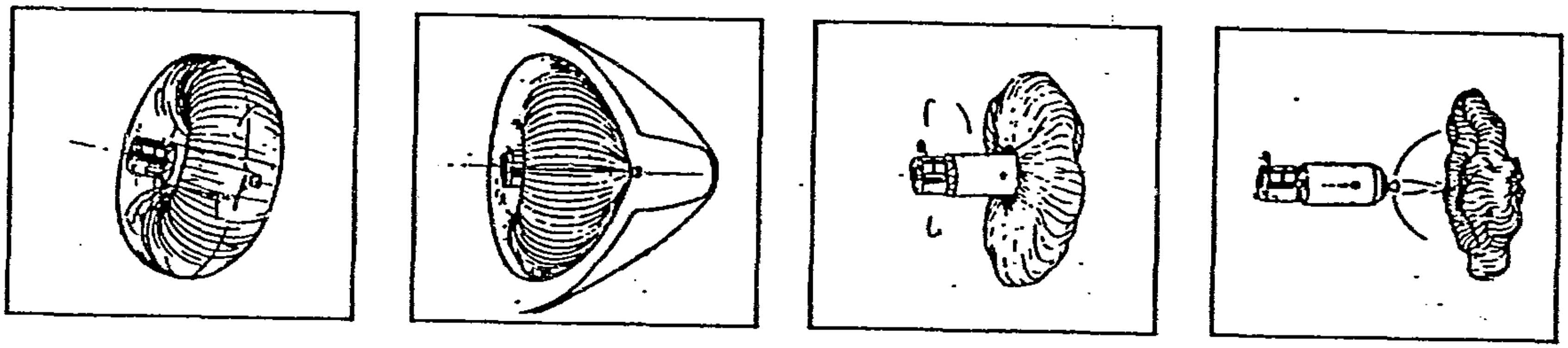
REFERENCE AEROBRAKER CONCEPT





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ASSUMED GENERIC CHARACTERISTICS:

I_{SP} = 470 SEC

λ = 0.875

REDUCTION IN ΔV_{RETURN} = 6000 FPS

TRAFFIC SENSITIVITIES

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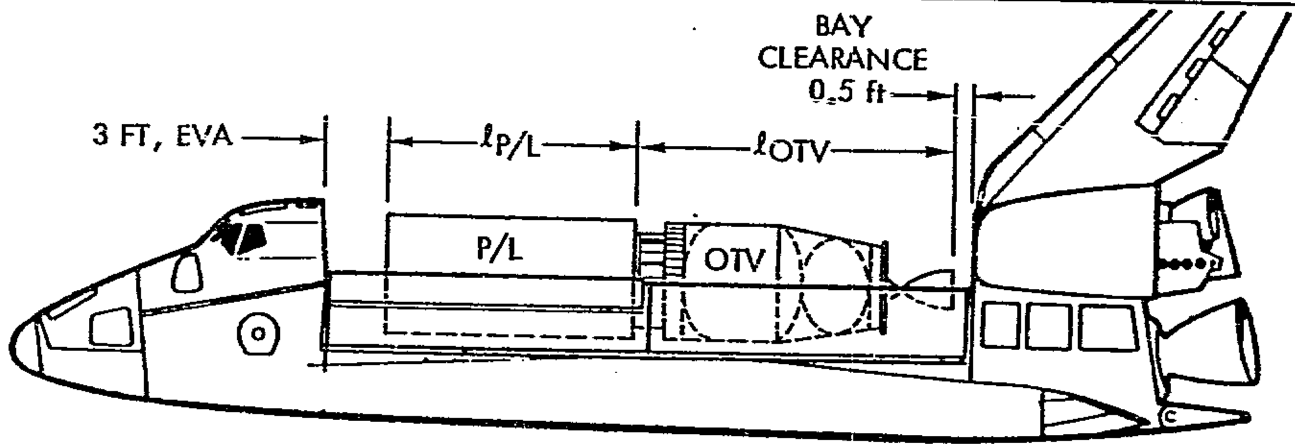
REFERENCE VALUES (11 YR TRAFFIC):
N = 247 FLIGHTS $\rho_{AVG} = 2.5 \text{lb/ft}^3$

FACTOR		ΔN SHUTTLE FLTS	ρ_{AVG} lb/ft^3
OTV PERFORMANCE:	$\Delta\lambda = -0.01$	+35 +26	2.5 5.3
	$\Delta Isp = -10$ sec	+19 +14	2.5 5.4
STS P/L PERF: 80K ORBITER		0 -57	2.5 7.1
AEROBRAKING		0 -27	2.5 6.3
NO SCAVENGING (a) 9000 lb/FLT (b) 3% LOAD FACTOR		+61 +12	-7% -1.3%
CONSTANT ALTITUDE STRATEGY		+52	3.5

OTV SIZING EFFECTS ON PAYLOAD DENSITY



$$\frac{W_{P/L}}{W_{OTV}} = f(I_{sp}, \lambda, \Delta V, \text{ EXPENDABLE/REUSABLE, AEROBRAKING})$$

	SPACE DESIGN REUSABLE	GRND DESIGN REUSABLE	GRND DESIGN EXPENDABLE	SPACE DESIGN AEROBRAKING
$\frac{W_{P/L}}{W_{OTV}}$	0.183	0.161	0.445	0.267

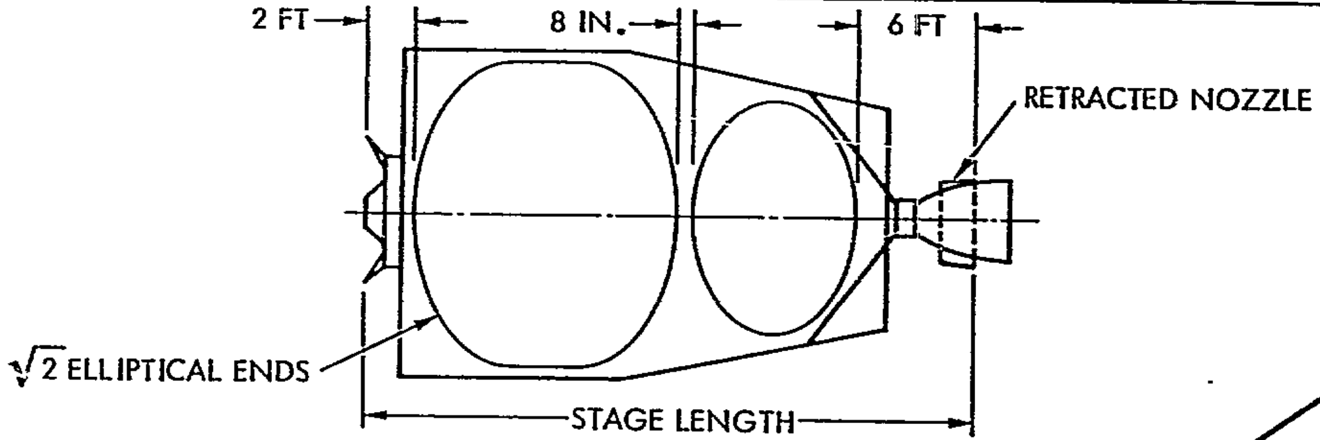
$$W_{GROSS} = W_{P/L} + W_{OTV} + 5000_{ASE} = \text{SHUTTLE LIMIT}$$

$$\ell_{OTV} = f(W_{OTV})$$

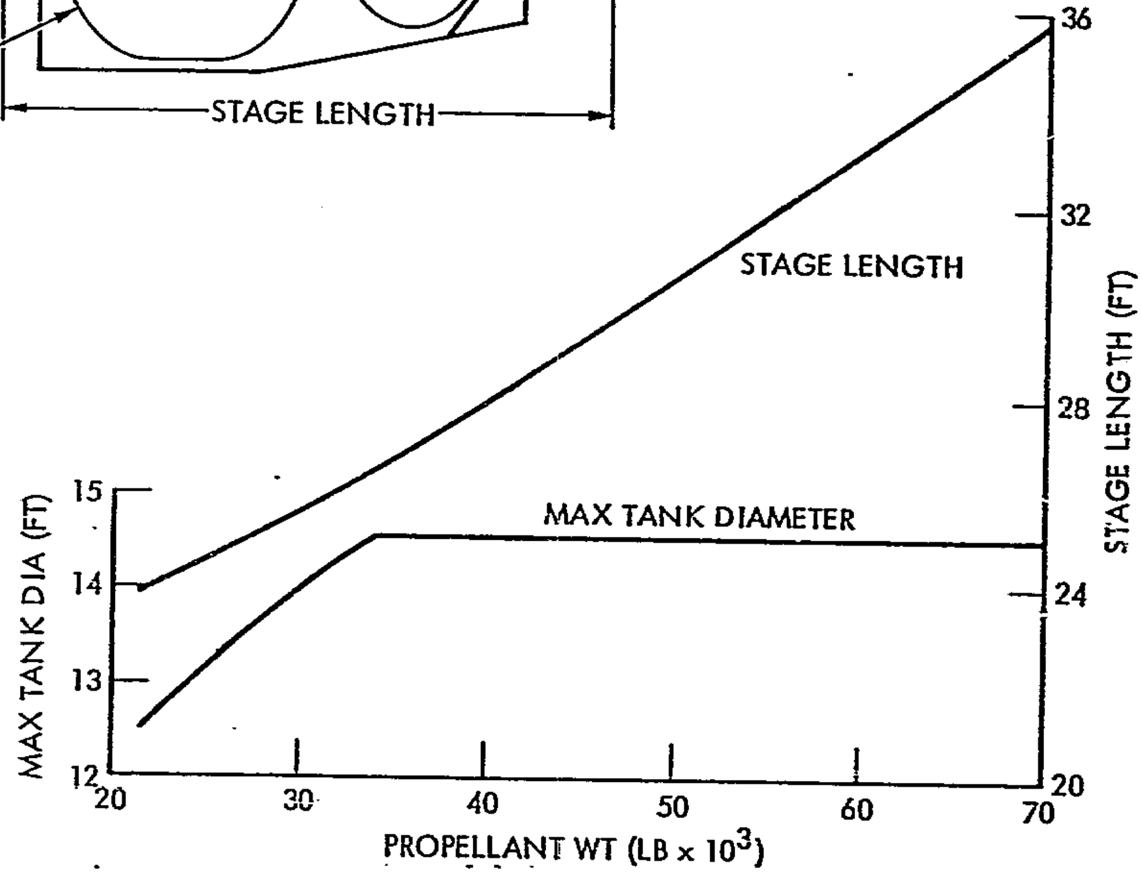
$$\ell_{P/L} = 60 - 3 - 0.5 - \ell_{OTV}, \text{ FT}$$

$$\boxed{\rho_{P/L} = \frac{W_{P/L}}{\ell_{P/L} \times 177} \quad \text{LB/FT}^3}$$

OTV STAGE LENGTH VS PROPELLANT WEIGHT



PROP TYPE	LH_2-LO_2
ΔV	14,500 FT/SEC
ISP	470 SEC
MIX RATIO	6
O_2 DENSITY	72 LB/FT^3
FUEL DENSITY	4.4 LB/FT^3
PROP ULLAGE	3%



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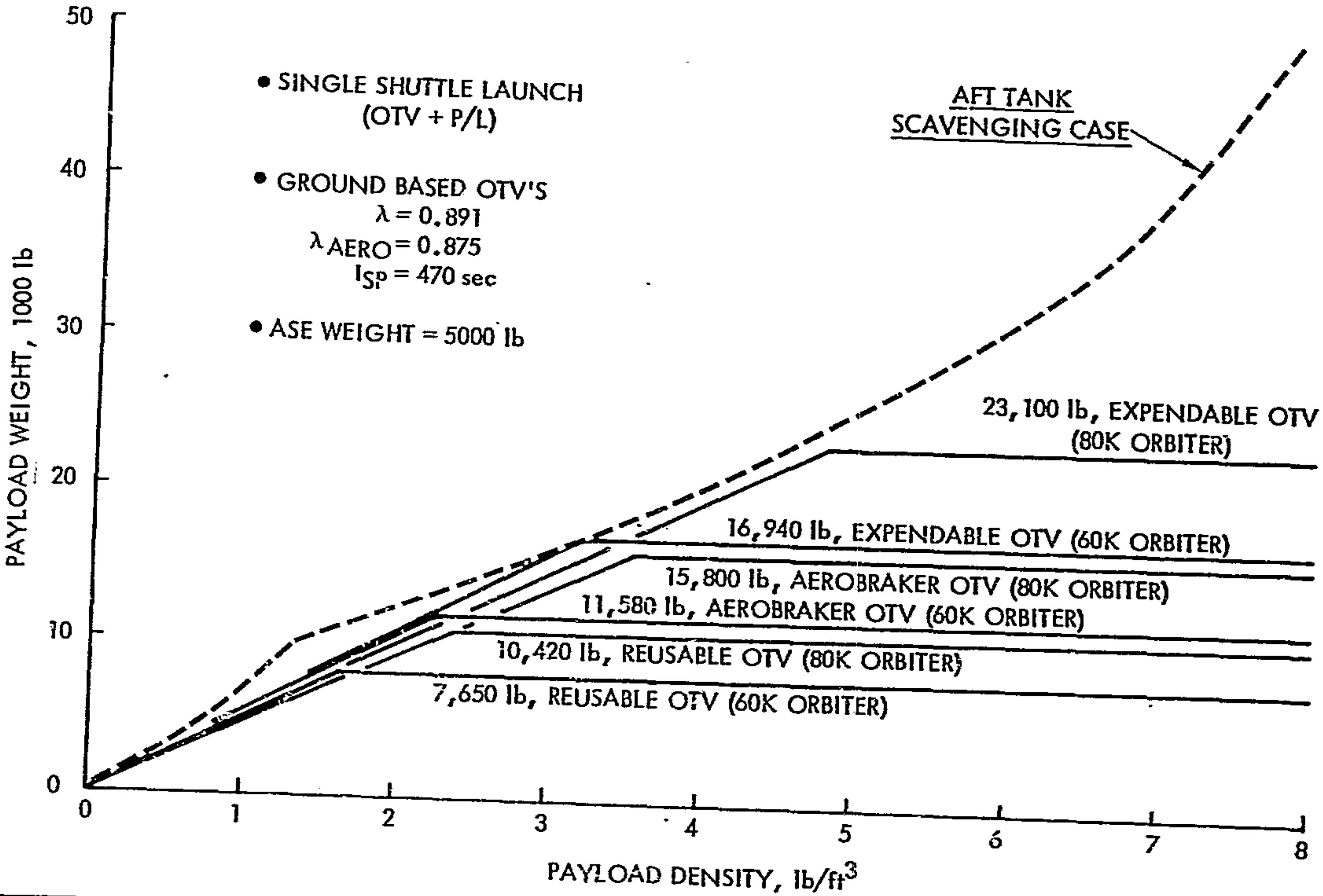
PAYLOAD DENSITY TRENDS WITH OTV PERFORMANCE



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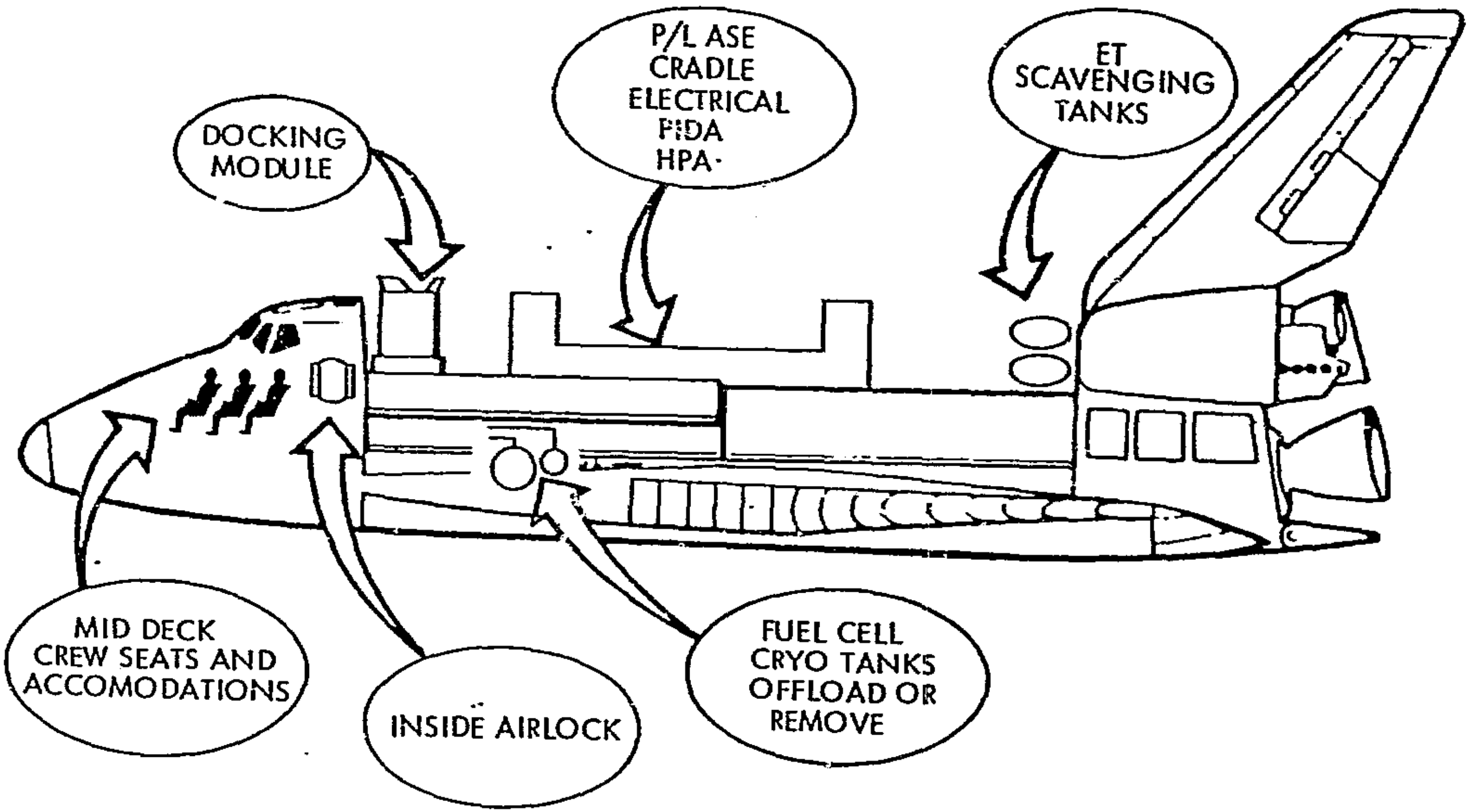
DEDICATED ORBITER CONSIDERATIONS



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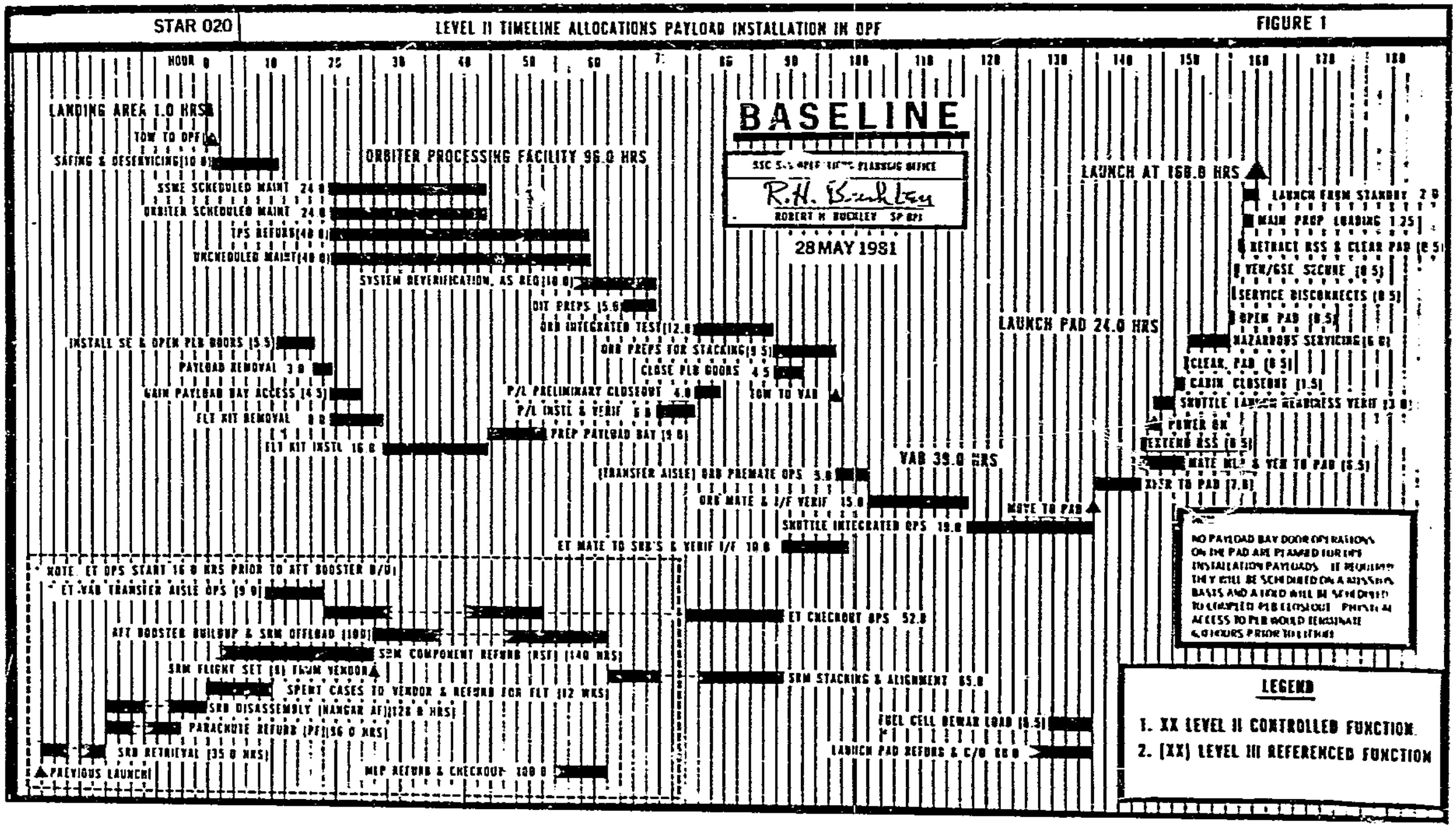
ORBITER TURNAROUND TIMELINE



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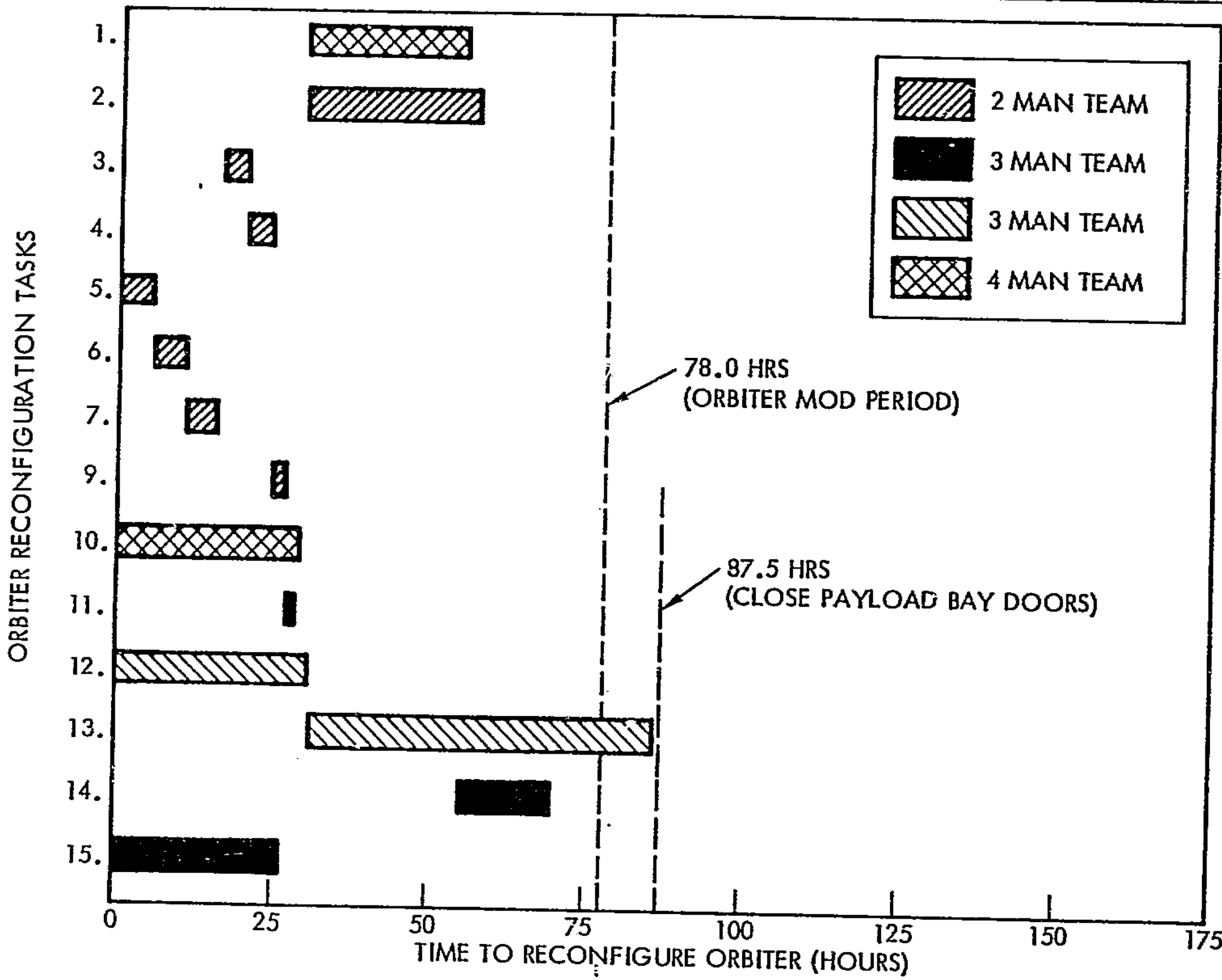
RECONFIGURE FROM MIXED CARGO TO SOC MISSION CONFIGURATION

TASK	HRS	MEN	TOTAL MHR
1. RECONFIGURE FROM MIXED CARGO HARNESS KIT TO SOC MISSION HARNESS KIT (B5)*	26.0	4.0	104.0
2. INSTALL LOGISTICS FLUIDS DUMP LINES KIT (B8)	28.0	2.0	56.0
3. REMOVE MIXED CARGO BALLAST KIT (B11)	4.0	2.0	8.0
4. INSTALL SOC MISSION BALLAST KIT (B11)	4.0	2.0	8.0
5. REMOVE MISSION STATION ACCOMMODATION KIT	5.5	2.0	11.0
6. REMOVE PAYLOAD STATION ACCOMMODATION KIT	5.5	2.0	11.0
7. INSTALL SOC ON-ORBIT STATION ACCOMMODATION KIT (B14)	5.5	2.0	11.0
8. REMOVE ONE SET OF FUEL CELL CRYO TANKS (B15)	60.0	4.0	240.0
9. INSTALL MID-DECK CREW SEATS AND ACCOMMODATIONS (B20)	3.0	2.0	6.0
10. INSTALL ET SCAVENGING TANKS (B23)	29.0	4.0	116.0
11. INSTALL PAYLOAD GRAPPLE FIXTURE (B25)	2.0	1.0	2.0
12. REMOVE INSIDE AIRLOCK (B25)	31.0	3.0	93.0
13. INSTALL DOCKING MODULE AND MOUNTING KIT (B31)	55.0	3.0	165.0
14. INSTALL PIDA (B32)	15.0	3.0	45.0
15. INSTALL HPA (B32)	27.0	3.0	81.0
	289.5	2.7	957.0

*APPENDIX B, KSC STS GROUND OPERATIONS PLAN, VOLUME III, STS FLIGHT KITS PLAN

TIME TO RECONFIGURE ORBITER FROM MIXED CARGO MISSION TO SOC MISSION CONFIGURATION



RECONFIGURE FROM SOC MISSION TO MIXED CARGO MISSION

TASK	HRS	MEN	TOTAL M-HRS
1. RECONFIGURE FROM SOC MISSION HARNESS TO MIXED CARGO HARNESS (B5)	26.0	4.0	104.0
2. REMOVE LOGISTICS FLUIDS DUMP LINES KIT (B8)*	16.0	2.0	32.0
3. REMOVE SOC MISSION BALLAST KIT (B11)	4.0	2.0	8.0
4. INSTALL MIXED CARGO BALLAST KIT (B11)	4.0	2.0	8.0
5. REMOVE SOC ON-ORBIT STATION ACCOMMODATION KIT (B14)	4.0	2.0	8.0
6. INSTALL MISSION STATION ACCOMMODATION KIT (B12)	7.5	2.0	15.0
7. INSTALL PAYLOAD STATION ACCOMMODATION KIT (B13)	7.0	2.0	14.0
8. INSTALL ONE SET OF FUEL CELL CRYO TANKS (B15)	415.0	4.0	1660.0
9. REMOVE MID-DECK CREW SEATS AND ACCOMMODATIONS (B20)	2.0	2.0	4.0
10. REMOVE ET SCAVENGING TANKS (B23)	22.0	4.0	88.0
11. REMOVE PAYLOAD GRAPPLE FIXTURE (B24)	1.0	1.0	1.0
12. REMOVE DOCKING MODULE AND MOUNTING KIT (B31)	16.0	3.0	48.0
13. INSTALL INSIDE AIRLOCK (B25)	55.0	3.0	165.0
14. REMOVE PIDA (B32)	18.0	3.0	54.0
15. REMOVE HPA (B32)	34.0	2.6	102.0
* APPENDIX B, KSC STS GROUND OPERATION PLAN, VOLUME III, STS FLIGHT KITS PLAN	631.0	2.6	2311.0

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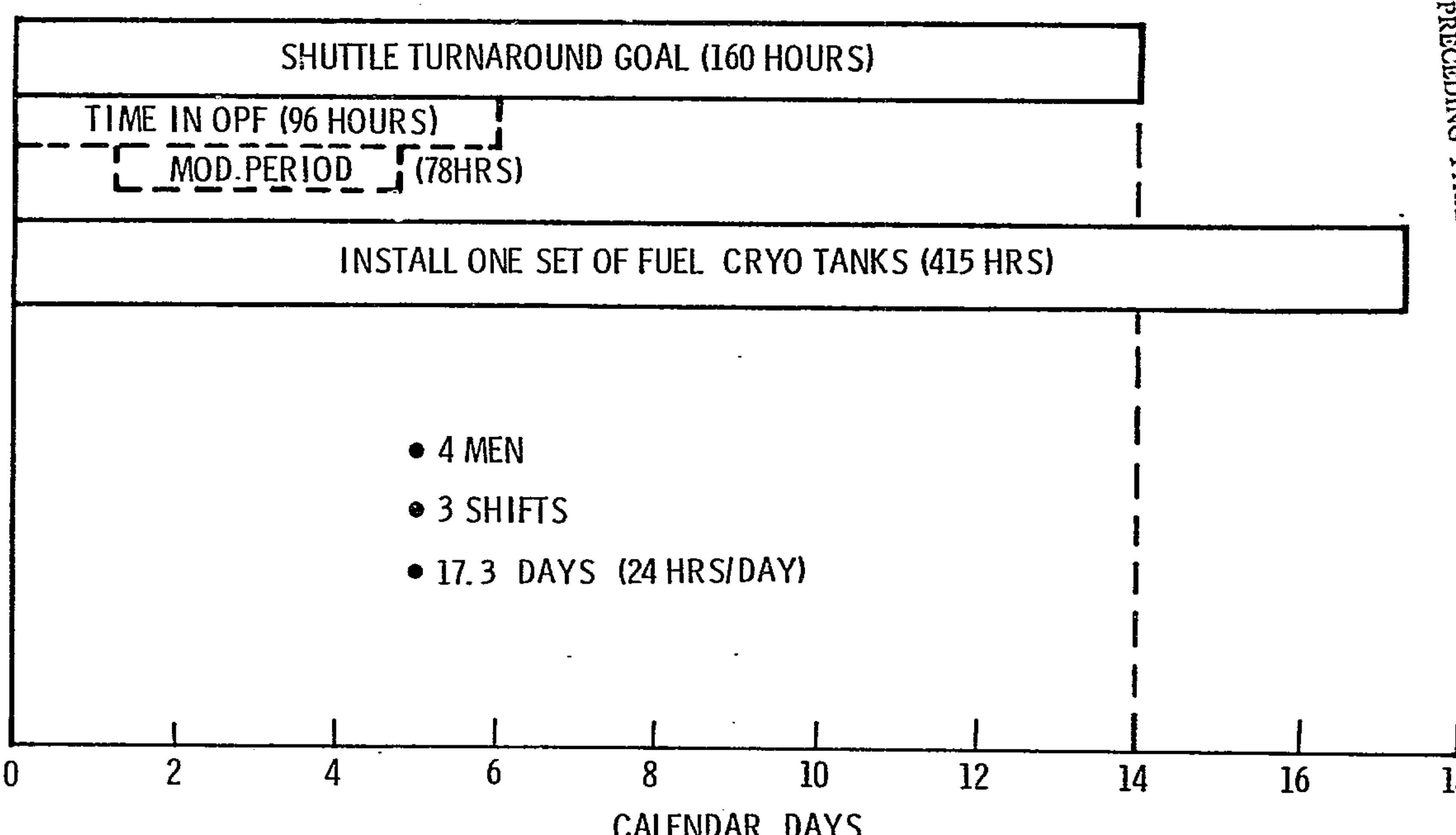
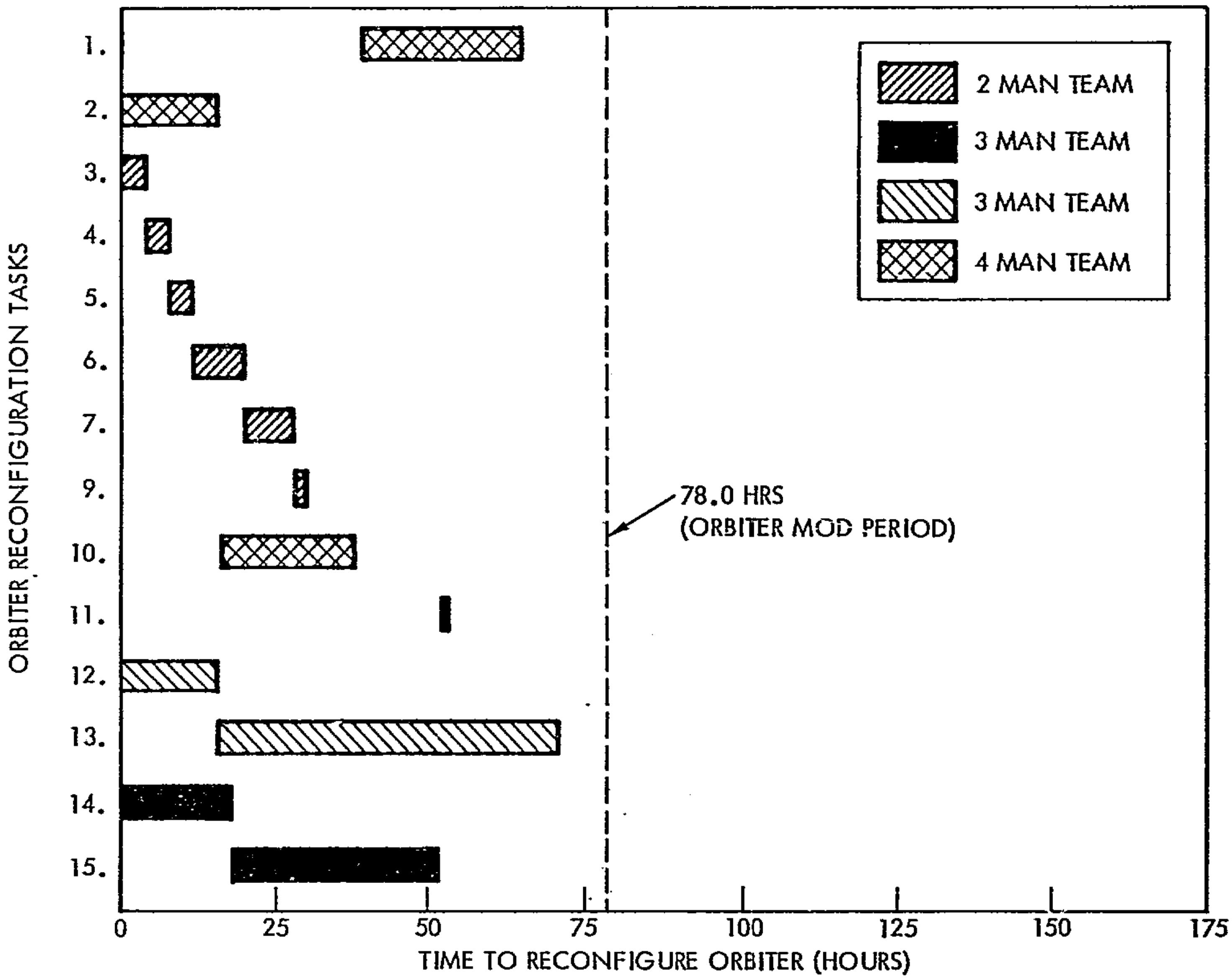
LIMITING FACTOR



TIME TO RECONFIGURE ORBITER FROM SOC MISSION TO MIXED CARGO MISSION CONFIGURATION



DEDICATED ORBITER BENEFITS

ITEM	WEIGHT LB	CONFIG TO SOC MAN-HRS	CONFIG TO M.C. MAN-HRS	COST**, $	BENEFIT*** $
1. CARGO HARNESS	TBD*	104	104	8320	TBD*
2. LOGISTICS FLUID DUMP LINES	TBD	56	32	3520	TBD
3. CARGO BALLAST KIT	TBD	8	8	640	TBD
4. CARGO BALLAST KIT	TBD	6	8	640	TBD
5. MISSION STATION KIT	TBD	15	11	1040	TBD
6. PAYLOAD STATION KIT	TBD	14	11	1000	TBD
7. SOC INTERFACE STATION KIT	TBD	11	8	760	TBD
8. FUEL CELL CRYO TANK SET	1320	240	1660	76,000	1,320,000
9. MID-DECK CREW SEATS	300	6	4	400	TO 300,000
10. ET SCAVENGE TANKS	VARIABLE	116	88	8160	>10,000,000
11. PAYLOAD GRAPPLE FIXTURE	≈50 – 100	2	1	120	TO 100,000
12. INSIDE AIRLOCK	900	93	165	10,320	900,000
13. DOCKING MODULE	4500	165	48	8520	4,500,000
14. PIDA	300	45	54	3960	300,000
15. HPA	1760	81	102	7320	1,760,000
16. RMS	1000	≈100	≈100	8000	1,000,000
17. RCS PROPELLANT	-802	0	0	0	762,000
18. OMS PROPELLANT	VARY WITH ORB ALT	0	0	0	TO 5,000,000

*MANIFEST DEPENDENT
**COST @ $40/HR
***BENEFIT @ $1000/LB TO LEO

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DEDICATED ORBITER BENEFITS SUMMARY

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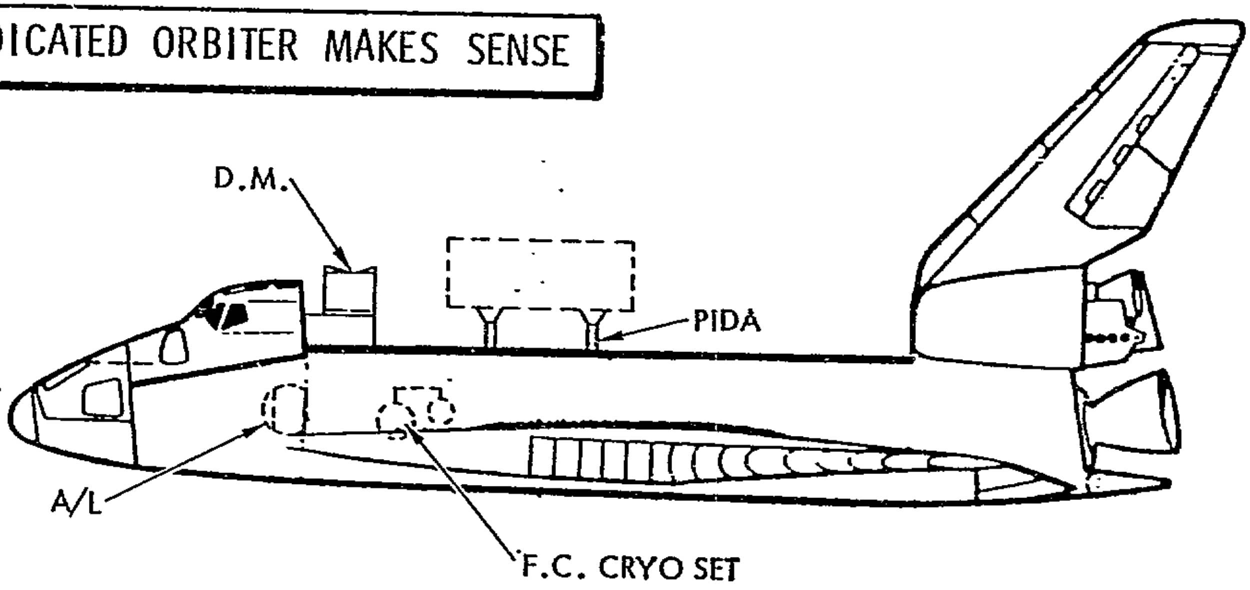
A DEDICATED ORBITER MAKES SENSE



STD CONFIG
- DOCKING MODULE
- NO INSIDE AIRLOCK
- ELIM ONE F.C. CRYO SET
- DUAL PIDA
- 1/2 C & D

- SAVES UP TO $\$25\overline{M}$ IN TURNAROUND COSTS
- YIELDS OVER $\$650\overline{M}$ EXTRA PROPELLANT TO ORBIT

FLEET SIZE REQUIREMENTS

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FLEET SIZE DEPENDS UPON

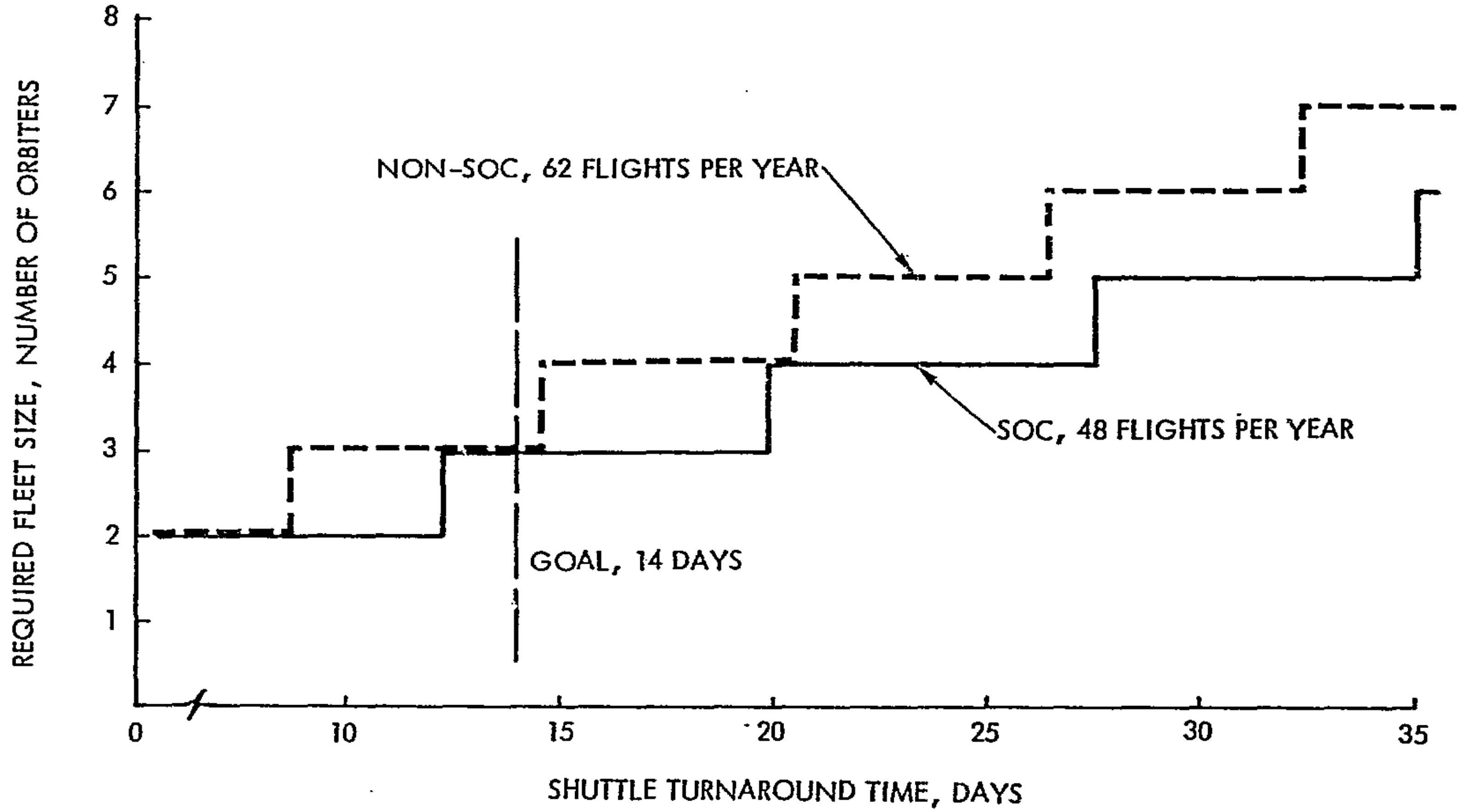
- FLIGHT RATE
- MISSION DURATION
- TURNAROUND TIME

$$N = \frac{(\text{FLT RATE}) \times (\text{DURATION} + \text{TURNAROUND})}{365}$$

CONTINGENCY ALLOWANCE

- MATURE SYSTEM BY 1990
- WEATHER
- WTR - ETR SCHEDULES & TRANSFER TIME, IF REQUIRED
- LAUNCH PRIORITIES ISSUES
  - DOD VS CIVIL
  - COMMERCIAL VS NASA
- INVESTMENT IN FACILITIES VS ORBITERS

TURNAROUND TIME EFFECTS ON FLEET SIZE



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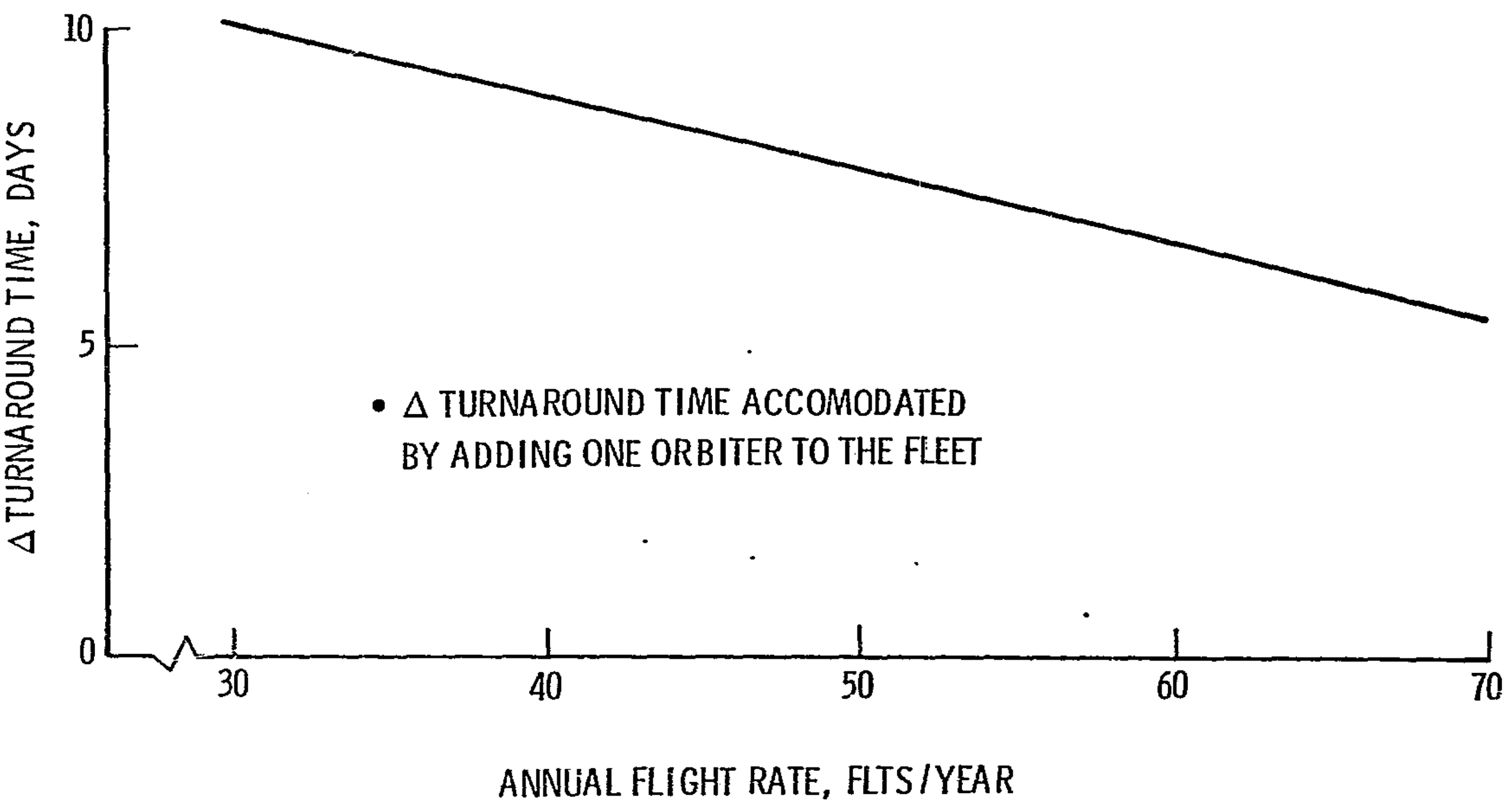
DELTA TURNAROUND SENSITIVITY TO FLIGHT RATE



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TASK 1.0 SUMMARY

SOC IS THE WAY TO GO

- SOC CAN SAVE OVER 200 SHUTTLE FLIGHTS OVER 20 YEAR SOC LIFE
  - APPROXIMATELY DOUBLES LOAD FACTOR
  - REDUCES FLIGHT RATE BY MORE THAN 20 PERCENT

    REDUCES FLEET SIZE BY AT LEAST ONE "BIRD"
- GAINS IN OTV PERFORMANCE & SHUTTLE LIFT CAPABILITY OFFER FURTHER COST SAVINGS . . . . BUT ONLY IF P/L PACKAGED DENSITY IS INCREASED (BOTH SOC & NO SOC)
- VARIABLE ALTITUDE STRATEGY FOR SOC OFFERS SIGNIFICANT LOGISTICS BENEFITS
- A DEDICATED ORBITER MAKES SENSE

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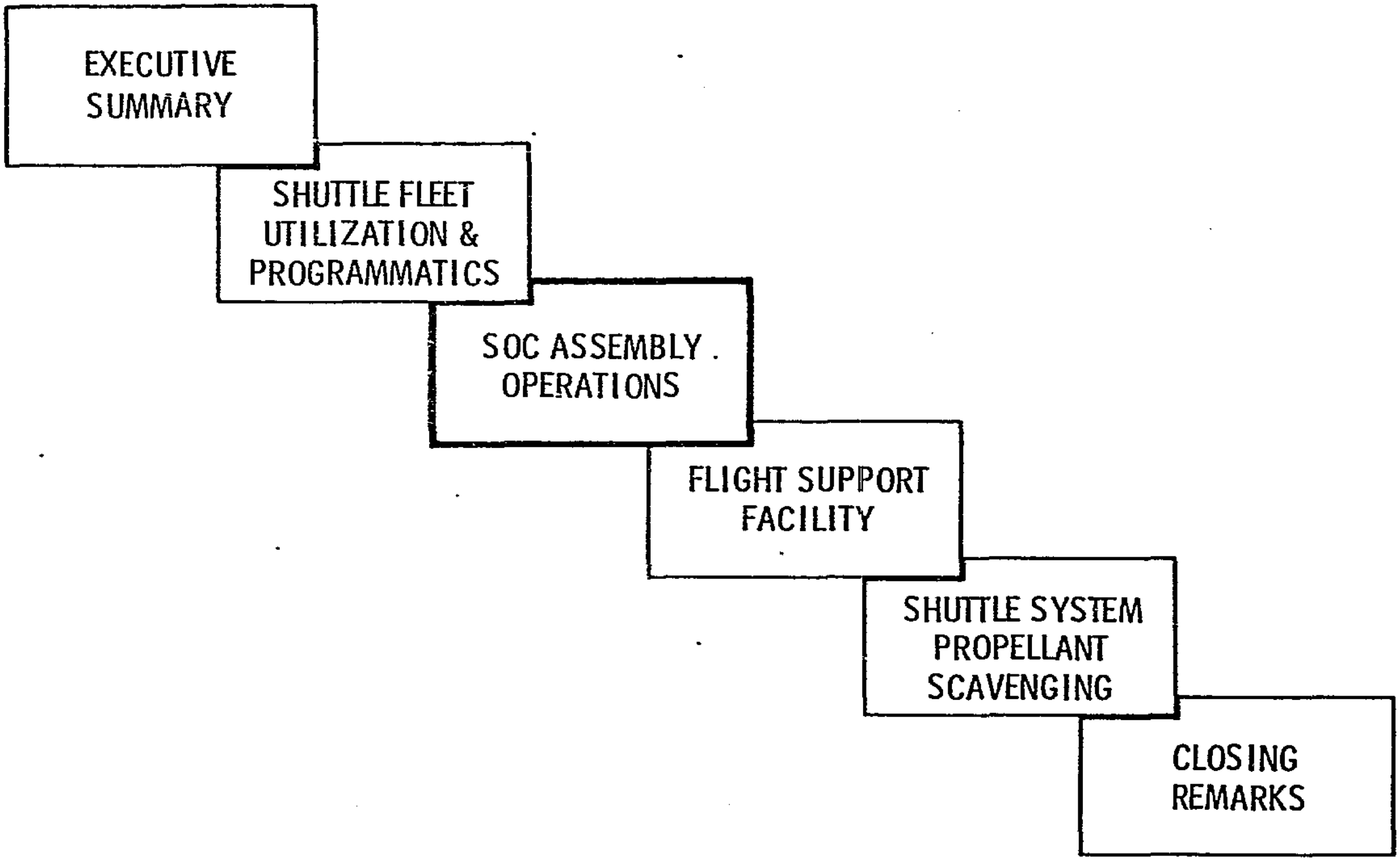


TASK 2 - SOC ASSEMBLY OPERATIONS OBJECTIVES

During the SOC/Shuttle Interaction Study, the feasibility of assembling the SOC by the orbiter RMS was investigated. The main investigation tools were 1/48 scale models of the orbiter and the SOC modules which were of sufficient fidelity to establish the feasibility of the assembly approach. In this extension study, the capability of the RMS to the assemble the SOC was to be confirmed. In addition, the implications of the assembly operations and those to the SOC were to be determined.

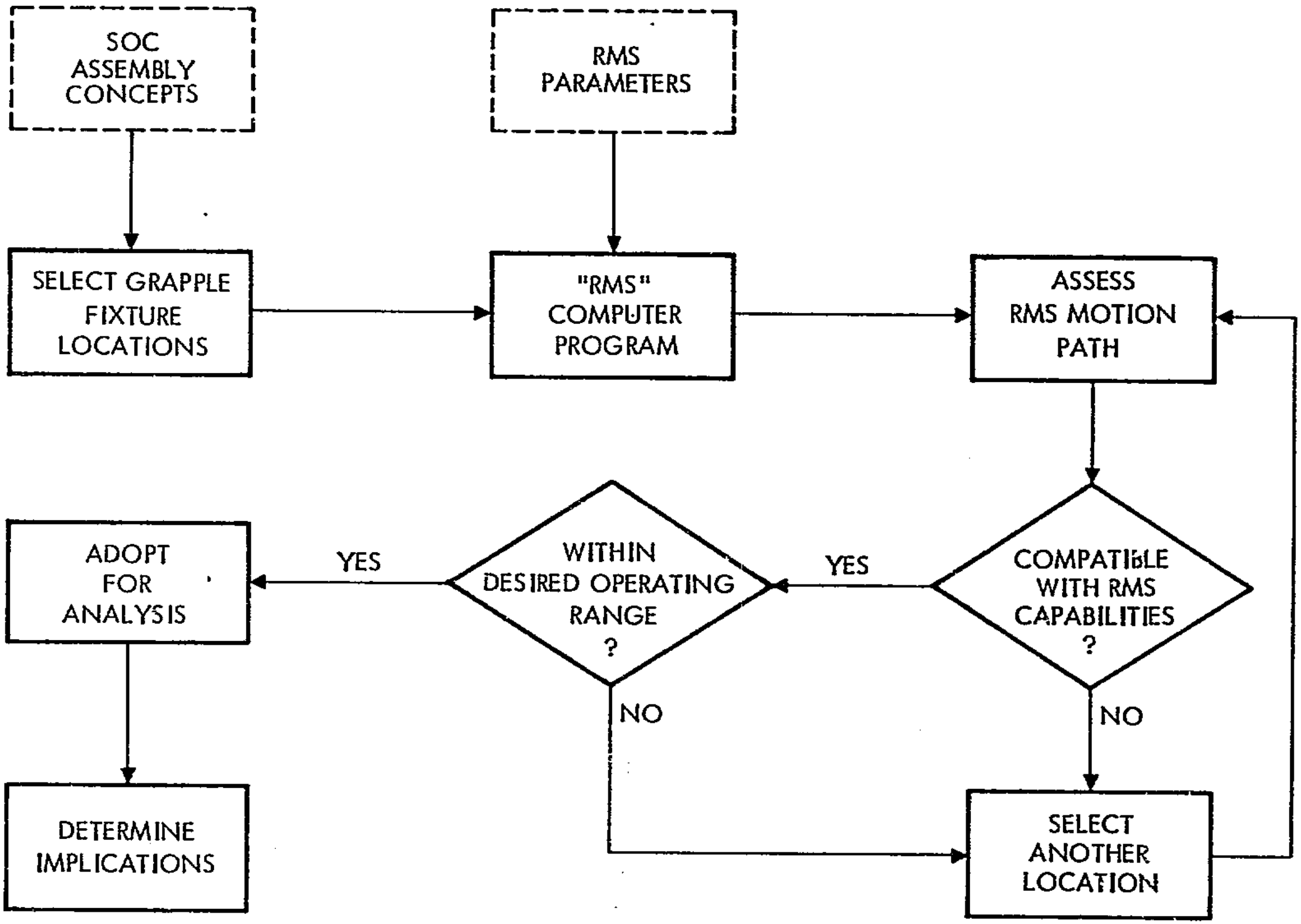
TASK 2 -- SOC ASSEMBLY OPERATIONS OBJECTIVES

- CONFIRM CAPABILITY OF RMS TO ASSEMBLE SOC
- DETERMINE ASSEMBLY OPERATIONAL IMPLICATIONS
- DETERMINE IMPLICATIONS TO SOC MODULES

TASK 2 - SOC ASSEMBLY OPERATIONS APPROACH

The main tool for achieving the objective of this task was the "RMS" Computer Program which is a kimematic analysis tool for assessing the RMS geometry in any given orientation. The input to the program was the initial and final coordinates of the RMS end effector as it grappled the various SOC modules. Once the assessment indicated that the selected grapple fixture locations are compatible with the RMS they wre adopted for determination of the implications.

TASK 2 - SOC ASSEMBLY OPERATIONS APPROACH



TASK 2 SUMMARY

Study results that were presented during the mid-term briefing are indicated. The emphasis in this final presentation was on developing an assembly procedure for Concept B and assessing the RMS capability in assembling it.

TASK 2 SUMMARY

<u>MIDTERM ACCOMPLISHMENTS</u>

- DEVELOPED "RMS" COMPUTER PROGRAM
- ASSESSED ASSEMBLY OF SOC REF CONFIGURATION (CONCEPT A)
- CONFIRMED CAPABILITY OF RMS TO ASSEMBLE CONCEPT A

<u>FINAL PRESENTATION</u>

- UPDATED CONCEPT A RESULTS
- DEVELOPED ASSEMBLY PROCEDURE FOR CONCEPT B (BOEING)
- ASSESSED & CONFIRMED RMS CAPABILITY TO ASSEMBLE CONCEPT B
- COMPARED CONCEPTS A & B
- DETERMINED IMPLICATIONS

SOC ASSEMBLY - CONCEPT A

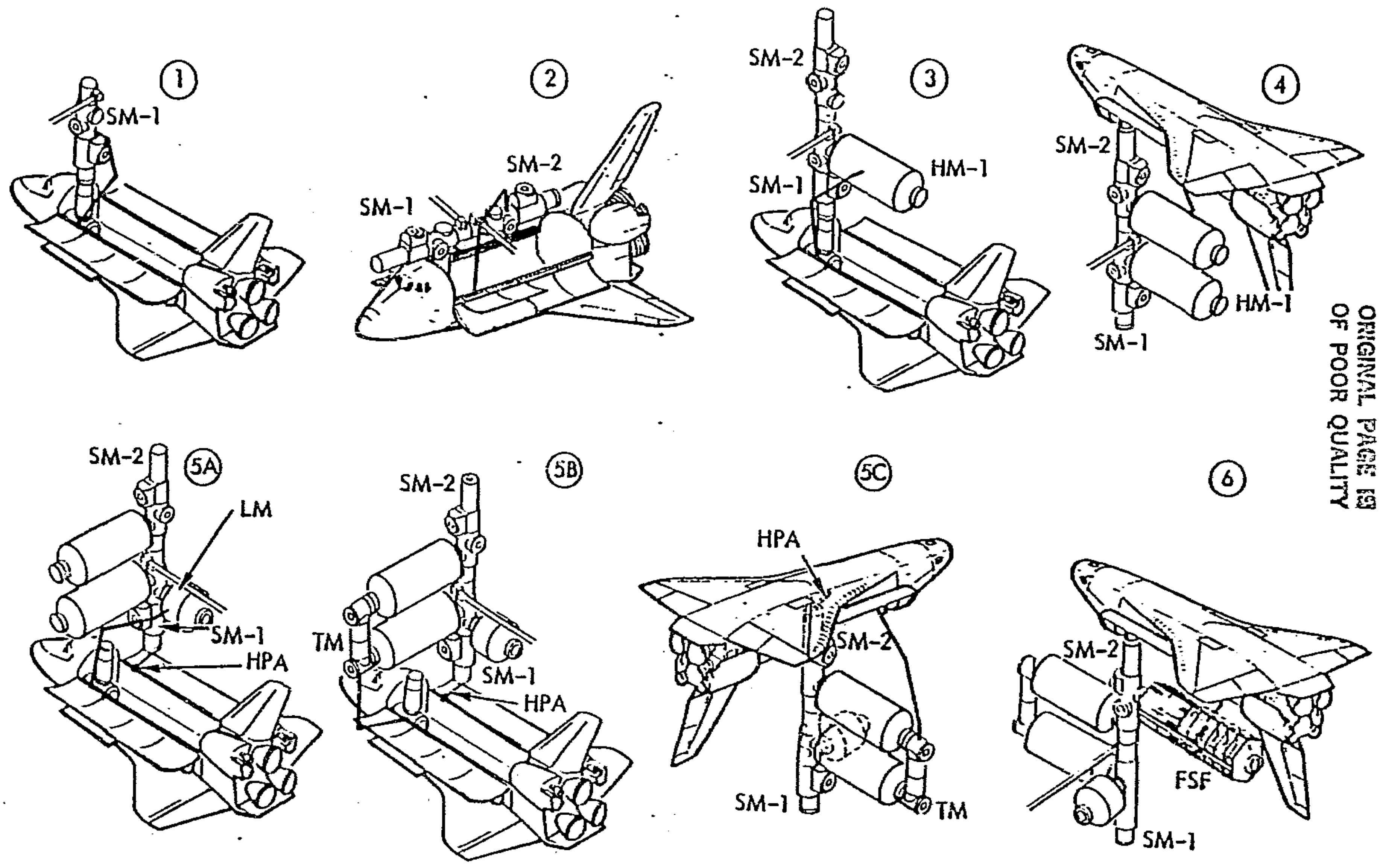
Designated as Concept A, the SOC reference configuration assembly starts by launching, deploying and checking out the first service module (SM-1) as depicted in the upper left-hand corner. Deployment of the SM-1 appendages and its checkout occur while it is berthed to the orbiter docking module. On the second flight, the orbiter will rendezvous and berth to a side port of SM-1 and attach the second service module (SM-2). Berthing of the orbiter to a side port is required to bring the assembly operation within the reach limit of the RMS. The first habitation module (HM-1) is launched and attached to the SOC on the third flight. Here, the orbiter-SOC interface is the end port of the SM-1. The second habitation module (HM-2) is attached in a similar manner as HM-1 on the fourth flight. However, the end port of SM-2 is used as the orbiter-SOC interface. Again, this is required to bring the assembly operation within the reach limit of the RMS.

The fifth flight in the SOC assembly sequence is the most complex of Concept A because two modules, the logistics module (LM) and the tunnel module (TM) are attached to the SOC. A standard RMS is not capable of attaching the TM by itself, regardless of which port is used as the orbiter-SOC interface. Consequently, another assembly tool, the Handling and Positioning Aid (HPA) is required to augment the RMS in this operation. The fifth flight operations start with berthing the SOC (end port of SM-1) to the HPA as depicted in 5A. Then the LM is deployed from the orbiter payload bay and attached to the SOC. Once the LM is secured, the TM is deployed and one of its ports is attached to the SOC as depicted in 5B. Attaching the second TM port requires the SOC to separate from the orbiter and reberth to the HPA at the end port of SM-2 as depicted in 5C. Otherwise, the second TM port would be outside the reach limit of the RMS. At this point in time, the assemby operations of the fifth flight would be complete and th SOC can be declared operational. To transfer the crew from th orbiter, however, the SOC must separate from its HPA interface and reberth at the orbiter docking module. This operation is not depicted in the chart.

The described operations of the fifth flight are not intended to imply that attachment of the LM must precede attachment of the TM. The reverse order is also a feasible alternative. Furthermore, it may be the preferred method if crew transfer provisions are normally associated with the end port of SM-1.

On the sixth flight of the SOC assembly operation, the flight support facility (FSF) is launched, deployed and atached to the SOC. It should be noted, again, that the orbiter-SOC interface is the end port of SM-2.

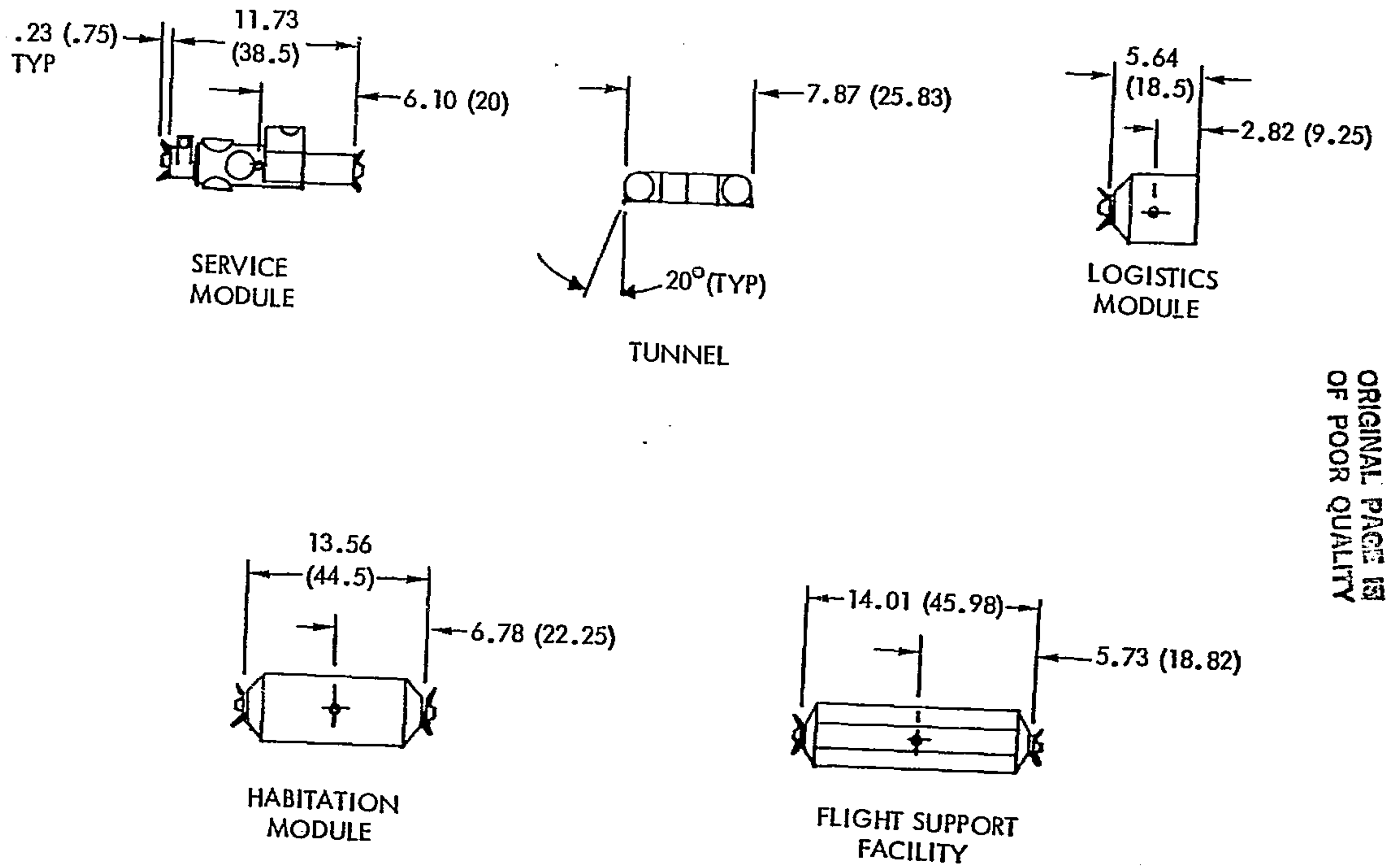
SOC ASSEMBLY - CONCEPT A



GRAPPLE FIXTURE LOCATIONS - CONCEPT A

To determine the inputs to the "RMS" computer program, grapple fixture locations were selected as indicated on the chart. Each grapple fixture was located oı the plane of the geometric center of each module. The exception is the TM where two grapple fixtures were located, one on each of its ends, as indicated in the chart. RMS reach limitations prevented the location of the TM grapple fixture in any other zone.

GRAPPLE FIXTURE LOCATIONS - CONCEPT A

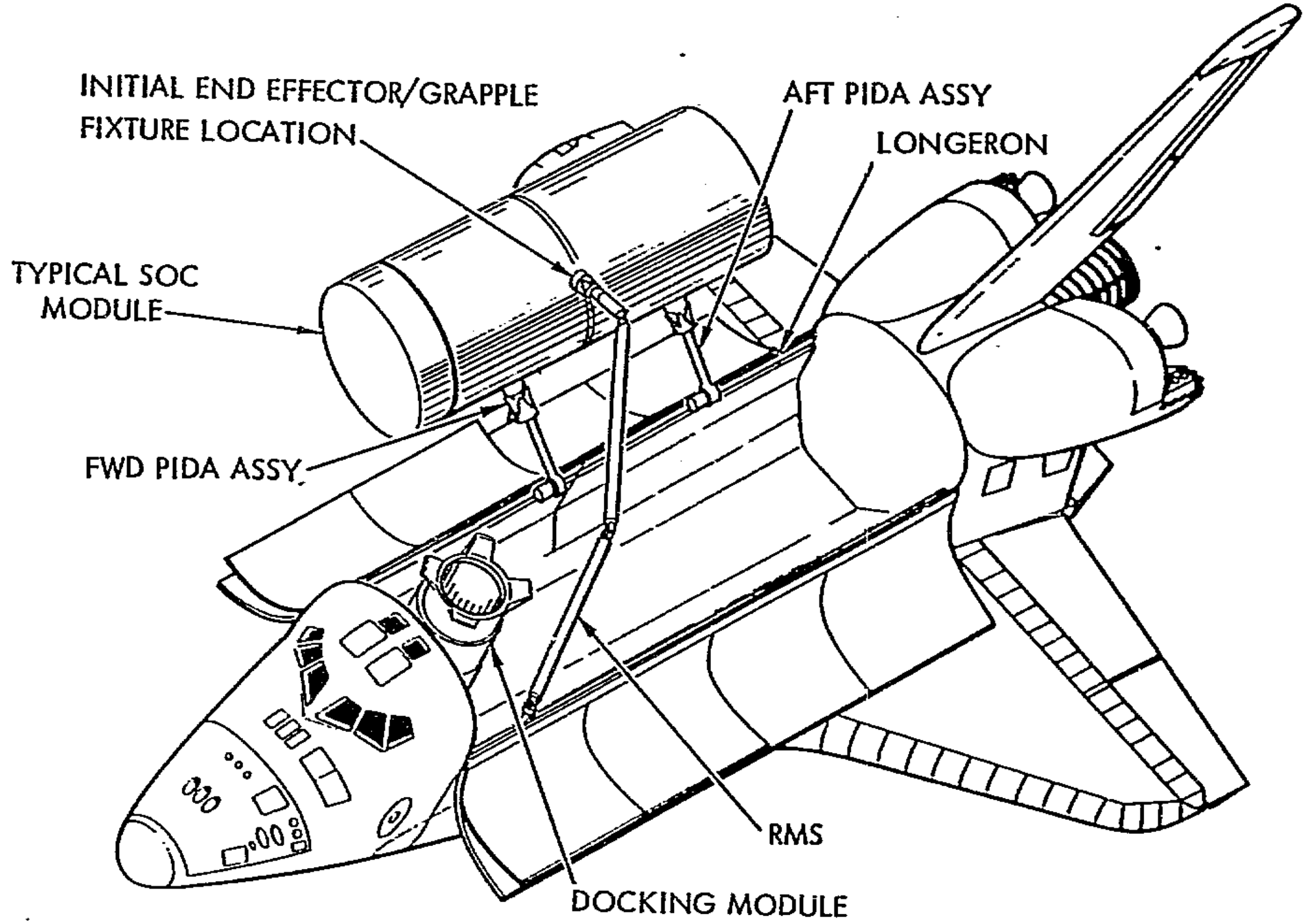


UNITS: METERS (FEET)

INITIAL END EFFECTOR/GRAPPLE FIXTURE LOCATIONS

Another step in the determination of the inputs to the "RMS" computer program was to locate and orient SOC module relative to the orbiter and establish an initial set of end effector coordinates. Since most of the SOC modules were assumed to be deployed from their stowed positions by the PIDA, the end effector/grapple fixture coordinates reflected the modules while attached to the PIDA outside the payload bay as indicated on the opposite chart.

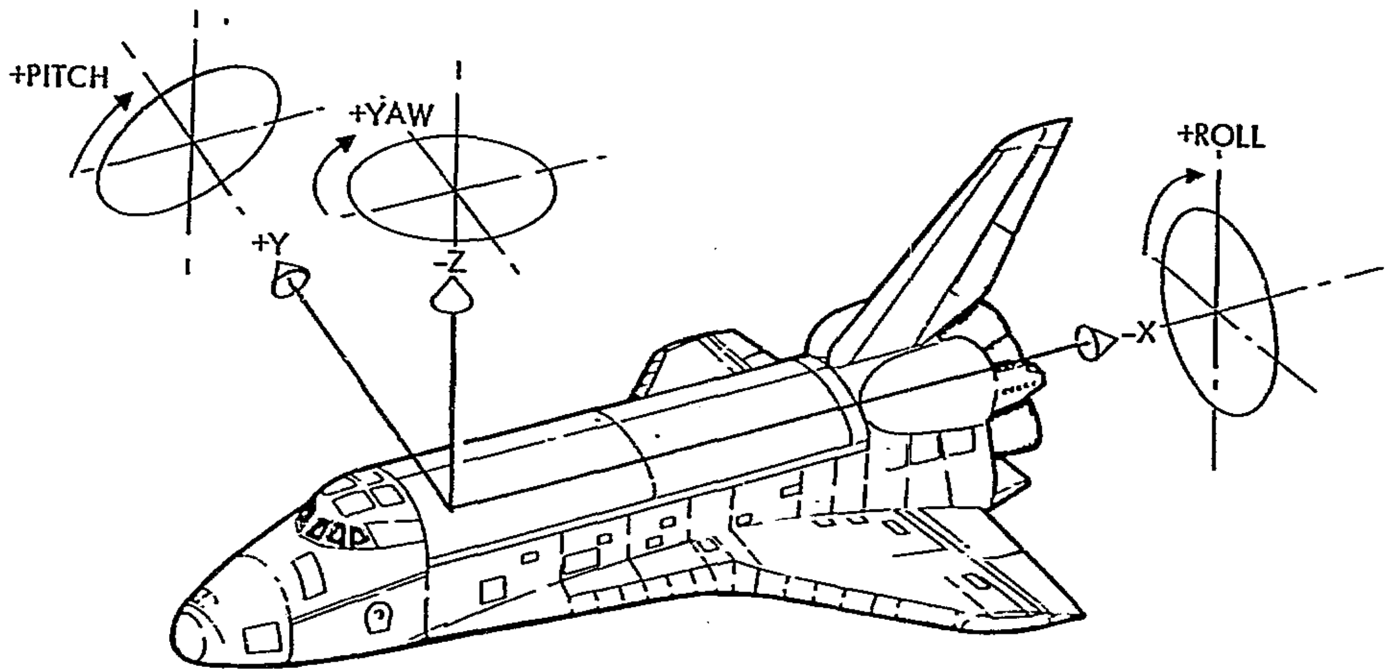
INITIAL END EFFECTORS/GRAPPLE FIXTURE LOCATION



TASK 2 - SIGN CONVENTION

The sign convention which was used in the computation of the inputs is illustrated on the opposite chart. It differs from the normal orbiter sign convention to accommodate the computer.

TASK 2 - SIGN CONVENTION



END EFFECTOR LOCATIONS
SOC ASSEMBLY - CONCEPT A

The initial and final RMS and effector coordinates were computed and inputted ito the "RMS" computer program. The resulting data points are listed on the opposite chart.

END EFFECTOR LOCATIONS
SOC ASSEMBLY - CONCEPT A

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FLIGHT NO.	PAY-LOAD	INITIAL RMS END EFFECTOR COORDINATES						FINAL RMS END EFFECTOR COORDINATES					
					WRIST ATTITUDE						WRIST ATTITUDE		
		Xo	Yo	Zo	P	Y	R	Xo	Yo	Zo	P	Y	R
1	SM-1	-1053.00	129.06	-568.88	-31	90	0	-621.00	-50.00	-755.00	0	90	0
2	SM-2	-1053.00	129.06	-568.88	-31	90	0	-963.00	-50.00	-571.00	0	90	0
3	HM-1	-976.00	99.92	-586.39	-31	90	0	-951.00	-84.00	-857.00	0	90	0
4	HM-2	-976.00	99.92	-586.39	-31	90	0	-951.00	-84.00	-857.00	0	90	0
5A	LM	-856.00	99.92	-586.39	-31	90	0	-852.50	155.00	-807.64	0	270	0
5B	TM	-982.00	0	-400.00	-70	0	0	-726.50	-399.00	-829.44	160	0	0
5C	TM	—	—	—	—	—	—	-726.50	-399.00	-829.44	160	0	0
6	FSF	-992.00	99.92	-586.39	-31	90	0	-967.00	-82.00	-857.00	0	90	0
DM INTERFACE		-621.00	0	-515.00									
HPA INTERFACE		-679.50	239.00	-520.64									

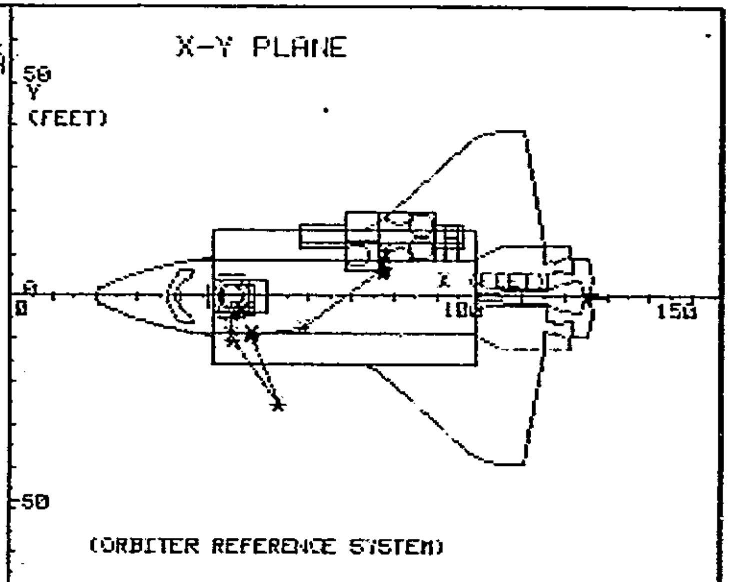
FLIGHT 1, SERVICE MODULE NO. 1
SOC ASSEMBLY - CONCEPT A

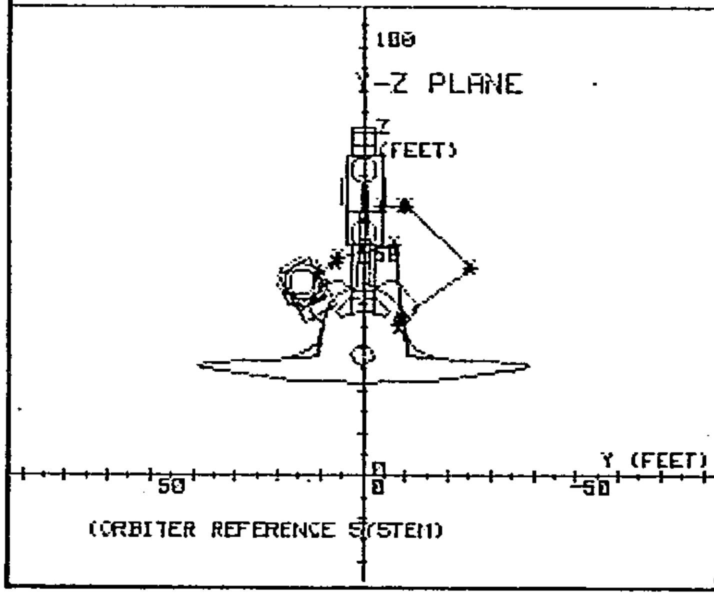
A typical output for each of the inputted data points is illustrated on the opposite chart. Besides the graphics of the particular operation, the output includes a recapitulation of the input data and the angular readings of each of the RMS joints related to the input data.

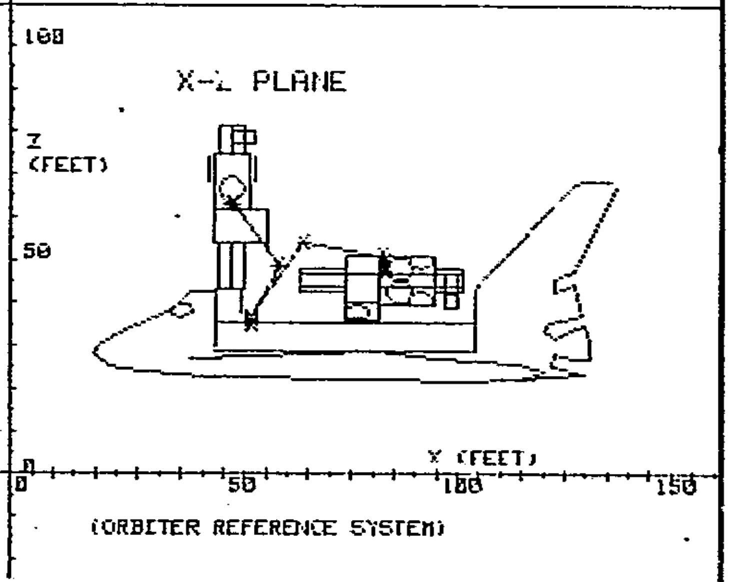
FLIGHT 1, SERVICE MODULE NO. 1
SOC ASSEMBLY - CONCEPT A

STOWED/DEPLOYED JOINT ANGLES & EE DATA

SY-	-31.508	-119.144
SP=	49.497	129.596
EP=	-69.392	-109.423
WP=	-46.783	-42.221
WY=	-32.856	27.331
WR-	-51.53	100.53
X EE-	-1053	-621
Y EE=	129.06	-50
Z EE=	-568.68	-755
PITCH EE	-31	0
YAW EE	90	90
ROLL EE	0	0







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RMS JOINT ANGLES - SOC ASSEMBLY CONCEPT A

A summary of the resultant RMS joint angle readings is shown on the opposite chart. It indicates that the SOC assembly operations can be accomplished by the RMS without exceeding any of it joint limits. However, there are five specific cases where the readings slightly exceeded a desired operating range for two specific joints. At the time of berthing a module, it is preferable if the RMS elbow pitch joint angle is not less than -40 degrees and the wrist yaw joint angle not more than ± 60 degrees. The five cases which exceeded those desired operating ranges are so indicated. They are not considered critical and can be eliminated by further iterations of the RMS computer program.

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RMS JOINT ANGLES - SOC ASSEMBLY CONCEPT A

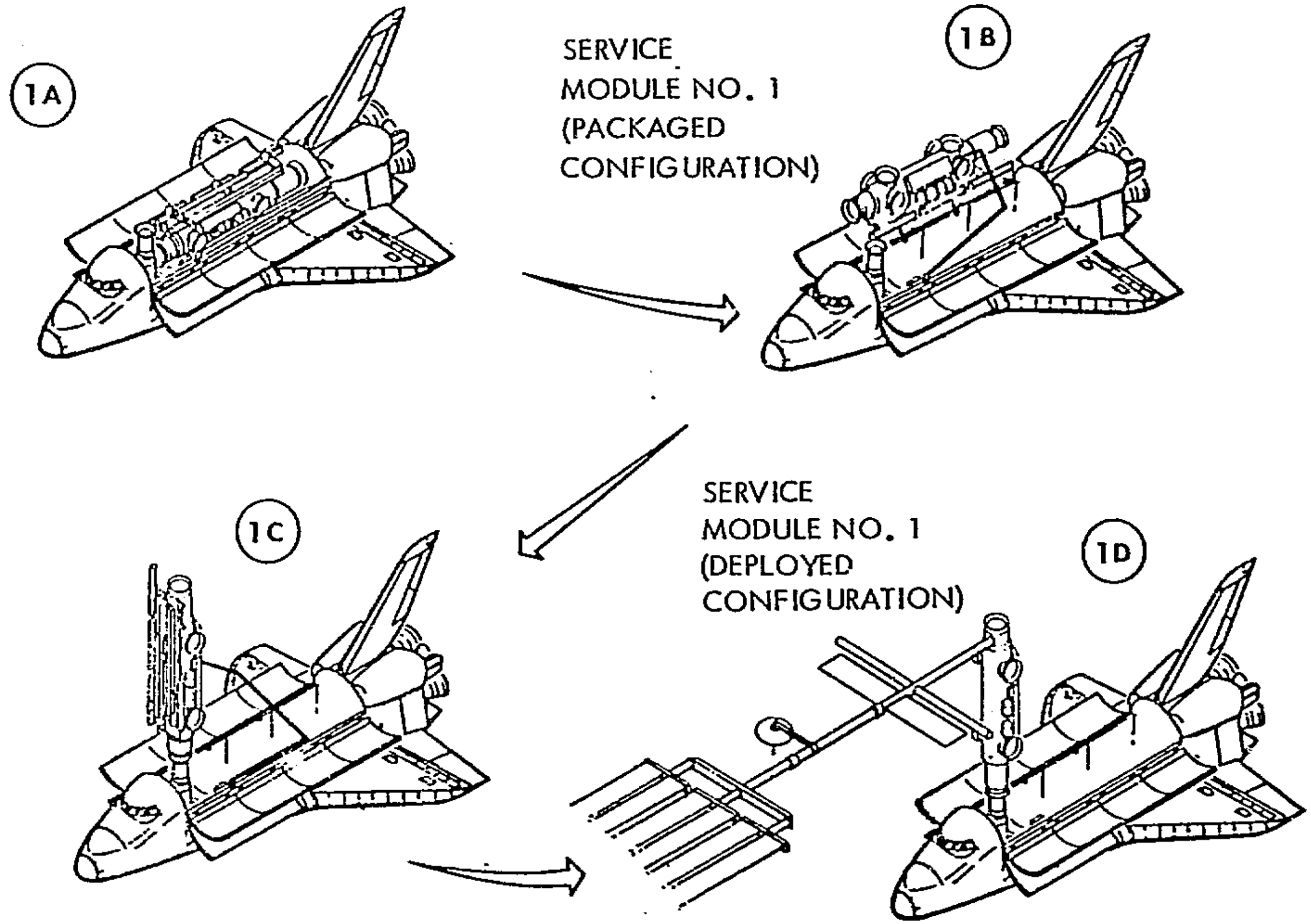
MODULE \ RMS JOINT (MAX LIMIT)	SY (-177.4 TO 177.4)	SP (0.6 TO 142.4)	EP (-0.4 TO -157.6)	WP (-116.4 TO 116.4)	WY (-116.6 TO 116.6)	WR (-442 TO 442)
SM-1 STOWED	-31.51	49.50	-69.39	-46.78	-32.86	-51.53
SM-1 DEPLOYED	-119.14	129.60	-109.42	-42.22	27.33	100.53
SM-2 STOWED	-31.51	49.50	-69.39	-46.78	-37.86 *	-51.53
SM-2 DEPLOYED	-8.73	85.31	-110.91	-41.17	-68.72	114.74
HM-1 STOWED	-34.96	68.48	-92.42	-40.76	-31.44 *	132.19
HM-1 DEPLOYED	-21.49	78.27	-42.47	-79.80	-61.31	139.73
HM-2 STOWED	-34.96	68.48	-92.42	-40.76	-31.44 *	132.19
HM-2 DEPLOYED	-21.49	78.27	-42.47	-79.80	-61.31	139.73
LM STOWED	-49.59	87.77	-118.34	-29.30	-24.36	147.00
LM DEPLOYED	-61.31	75.58	-68.93	-28.61	-26.91	169.66
TM STOWED	-20.27	59.44	-114.29	-21.67	24.36	-75.00
TM DEPLOYED	56.74	94.02	-54.29	112.14	46.31	130.00
FSF STOWED	-33.56	65.64	-88.43 *	-42.70	-32.02 *	131.00
FSF DEPLOYED	-20.72	73.61	-36.52	-82.09	-61.86	138.50

*JOINT ANGLES EXCEEDING DESIRED RANGE (EP>40°; WY<±60°)

SOC ASSEMBLY - CONCEPT B
FLIGHT 1

SOC Concept B, which was developed by the Boeing Aerospace Co., was subjected to a similar investigative process as Concept A. However, an assembly procedure was developed first as depicted in the next six charts. In the first flight, shown on the opposite chart, the first service module is launched and deployed from the payload bay by the PIDA. Then it is grappled by the RMS, berthed to the orbiter docking module, and, from this position, the solar array boom and its appendages can be deployed.

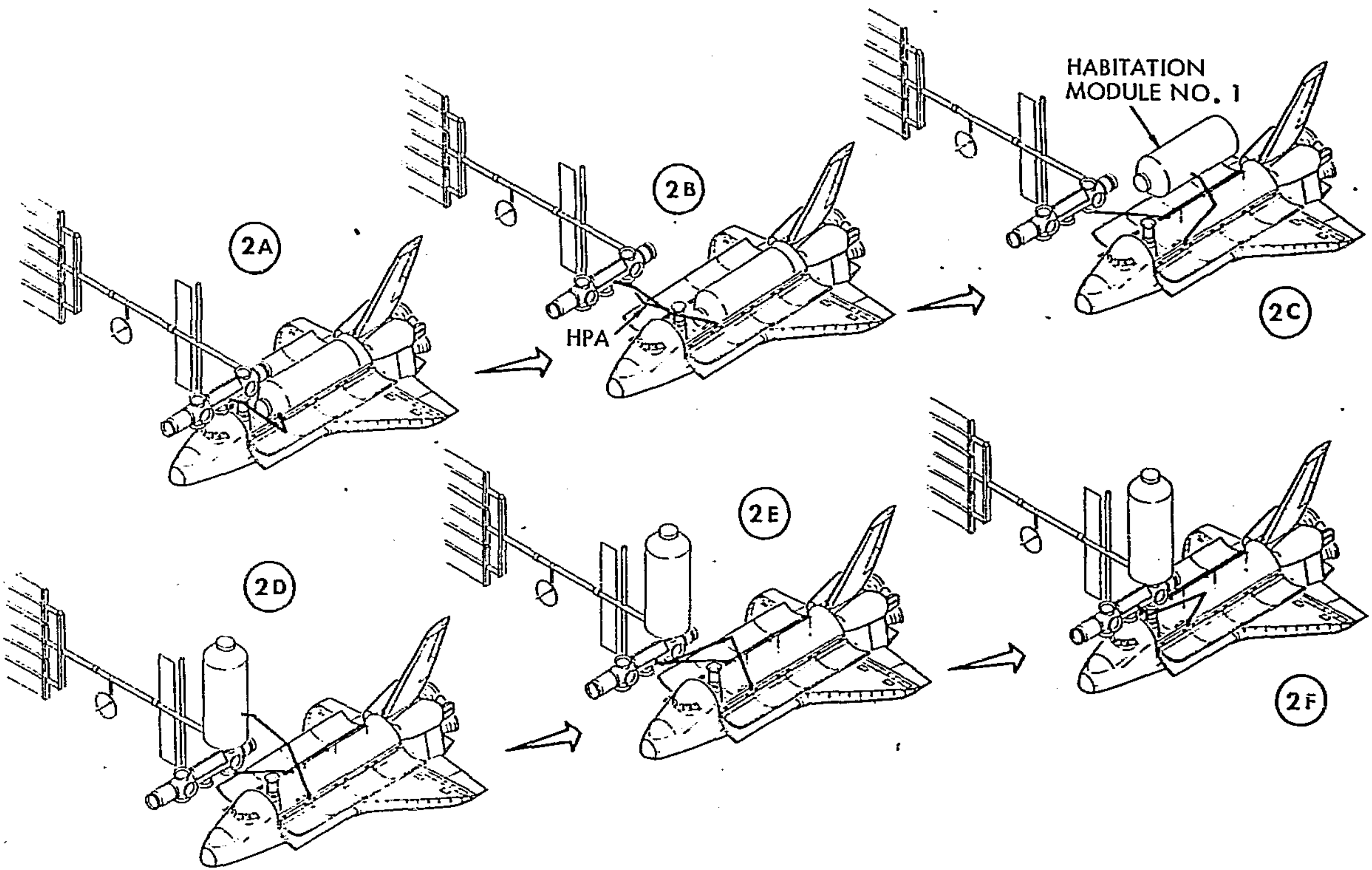
SOC ASSEMBLY - CONCEPT B
FLIGHT 1



SOC ASSEMBLY - CONCEPT B
FLIGHT 2

In the second flight of Concept B, a docking operation to a side port of service module no. 1 is required similar to that of Concept A. However, the payload in this case is the first habitation module. Subsequent to the docking operation, service module no. 1 must be transferred to the HPA interface as indicated. Because of its overall length, berthing service module no. 1 with the HPA is necessary to provide sufficient clearance for deploying the habitation module out of the payload bay. Once deployed, the habitation module is grappled by the RMS, transferred and berthed to the appropriate port on service module no. 1. The final operation is to transfer the entire assembly back onto the orbiter docking module. The last operation will allow crewmen access into the assembly it if is required as part of the checkout sequence.

SOC ASSEMBLY - CONCEPT B
FLIGHT 2

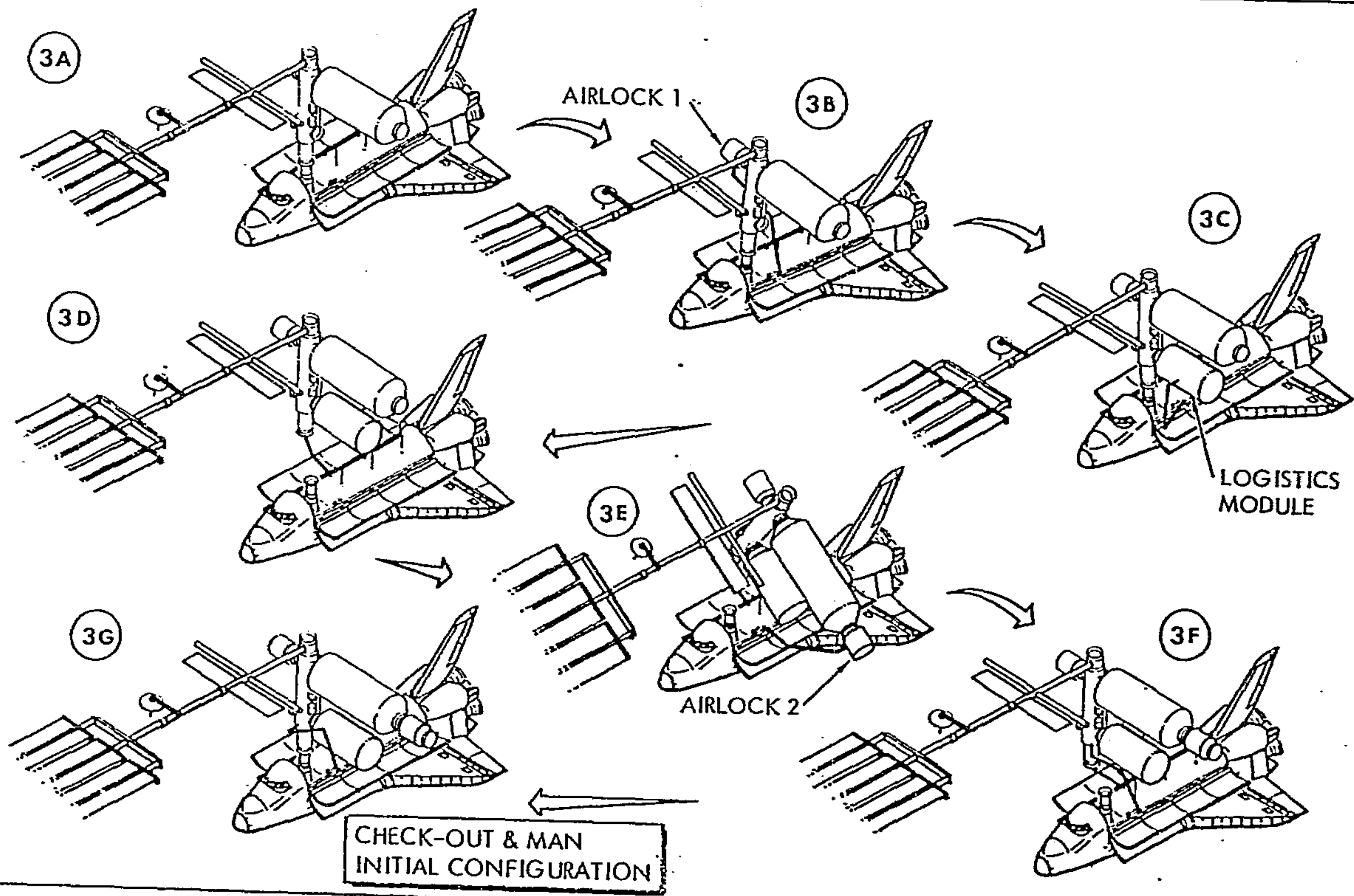


SOC ASSEMBLY - CONCEPT B
FLIGHT 3

Three separate modules constitute the payload in the third flight, the logistics module and two airlocks. In Concept A, each airlock was assumed to be an integral part of one service module. Concept B was the result of a service module packaging investigation which indicated the need to separate the airlock from the service module to permit a feasible stowage arrangement of the solar array boom and its appendages.

Once the orbiter is docked to the SOC assembly, airlock no. 1 is grappled by the RMS from inside the payload bay and attached as indicated. Then, the logistics module is deployed from the payload by the PIDA, grappled by the RMS, transferred and berthed as shown. Further operations require transferring the SOC assembly to the HPA interface where it is tilted toward the port side. This maneuver is necessary to bring in the next activity, attachment of the second airlock, within the reach of the RMS. The second airlock can then be grappled by the RMS, transferred and berthed to the end of the habitation module. To complete the operations to flight 3, the SOC must be transferred back on the docking module where it is checked out and manned. At this time, the four-man initial configuration of the SOC can be declared operational.

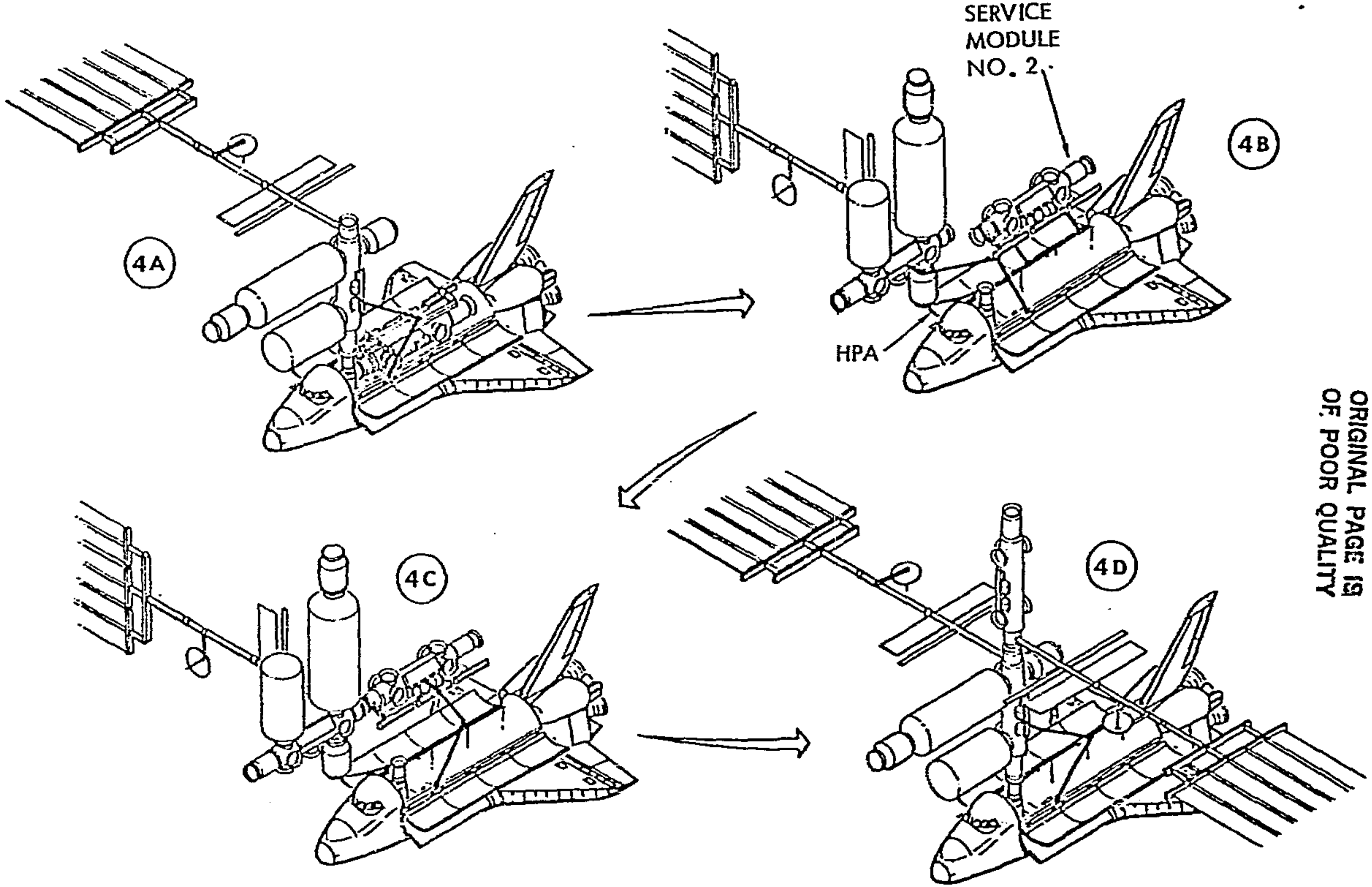
SOC ASSEMBLY - CONCEPT B
FLIGHT 3



SOC ASSEMBLY - CONCEPT B
FLIGHT 4

Flight 4 continues the SOC assembly toward a full operational configuration by attaching the second service module to the SOC. Once the orbiter docks to the SOC and transfers it to the HPA. The second service module can then be deployed from the payload bay by the PIDA where the RMS can grapple, transfer and berth it to the SOC. To deploy the solar panels of the second service mdule, the entire SOC must first be transferred to the docking module to provide sufficient clearances for the deployment operation. System checkout will follow the deployment of the solar panel and its appendages.

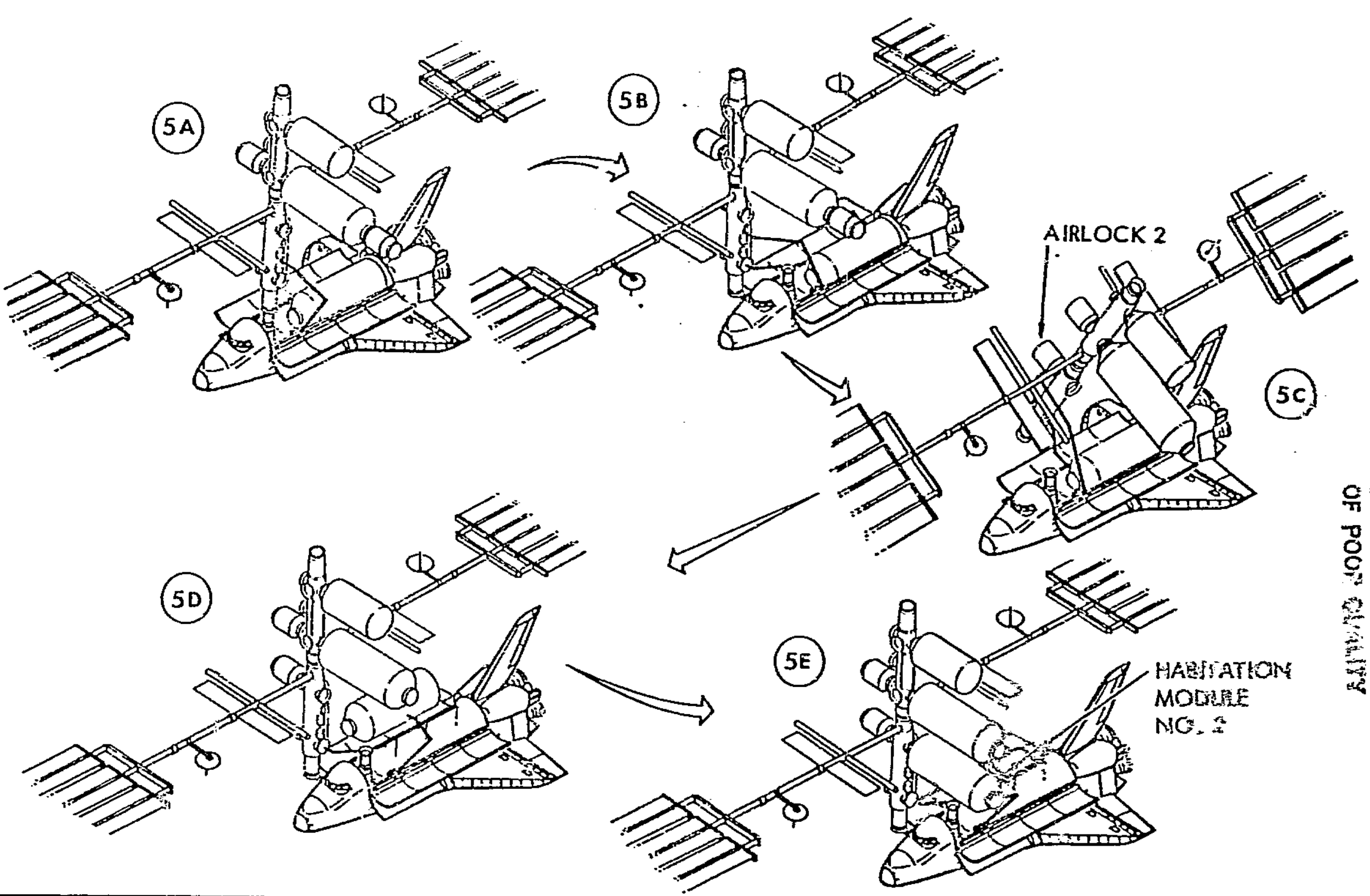
SOC ASSEMBLY - CONCEPT B
FLIGHT 4



SOC ASSEMBLY - CONCEPT B
FLIGHT 5

The second habitation module is the payload of flight 5 and prior to its attachment to the SOC, a rearangement of the SOC configuration is necessary. Airlock no. 2 must be removed from the end of the habitation module to its permanent berthed position on the side of service module no. 2. To accomplish the removal of airlock 2, the SOC is transferred to the HPA after docking of the orbiter to it. The HPA tilts the SOC toward the port side where airlock no. 2 can be reached by the RMS. The airlock is grappled by the RMS, released from its interface, transferred and berthed to the side of service module no. 2. Habitation module no. 2 can now be deployed out of the payload bay by the PIDA, then grappled by the RMS, transferred and berthed to service module no. 2.

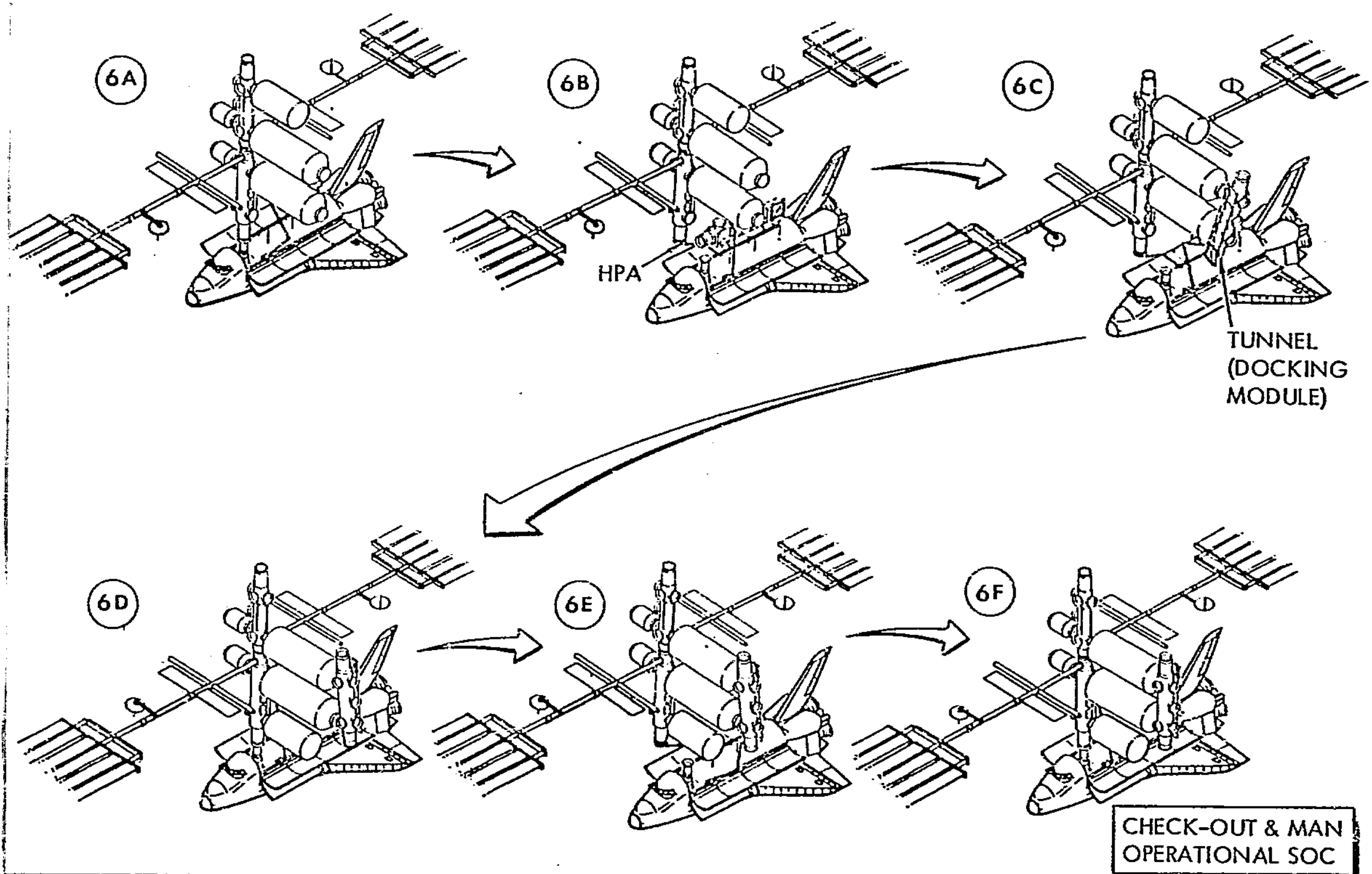
SOC ASSEMBLY - CONCEPT B
FLIGHT 5



SOC ASSEMBLY - CONCEPT B
FLIGHT 6

Only the tunnel needs to be added to the SOC to make it a complete operational configuration. The tunnel is the payload for flight 6 where its attachment to the SOC is similar to that of Concept A. After docking to the SOC, the orbiter RMS transfers the SOC to the HPA interface. The tunnel is then deployed from the payload bay by the FIDA where it is grappled by the RMS, transferred and one of its ports berthed to habitation module no. 1. To attach the tunnel's second port, the orbiter must release itself from the HPA, fly around and dock to the end of service module no. 2. The RMS grapples the end of the tunnel and mates its second port to habitation module no. 2. For a complete checkout of the SOC and transfer of the crew, the SOC must be reberthed to the orbiter docking module.

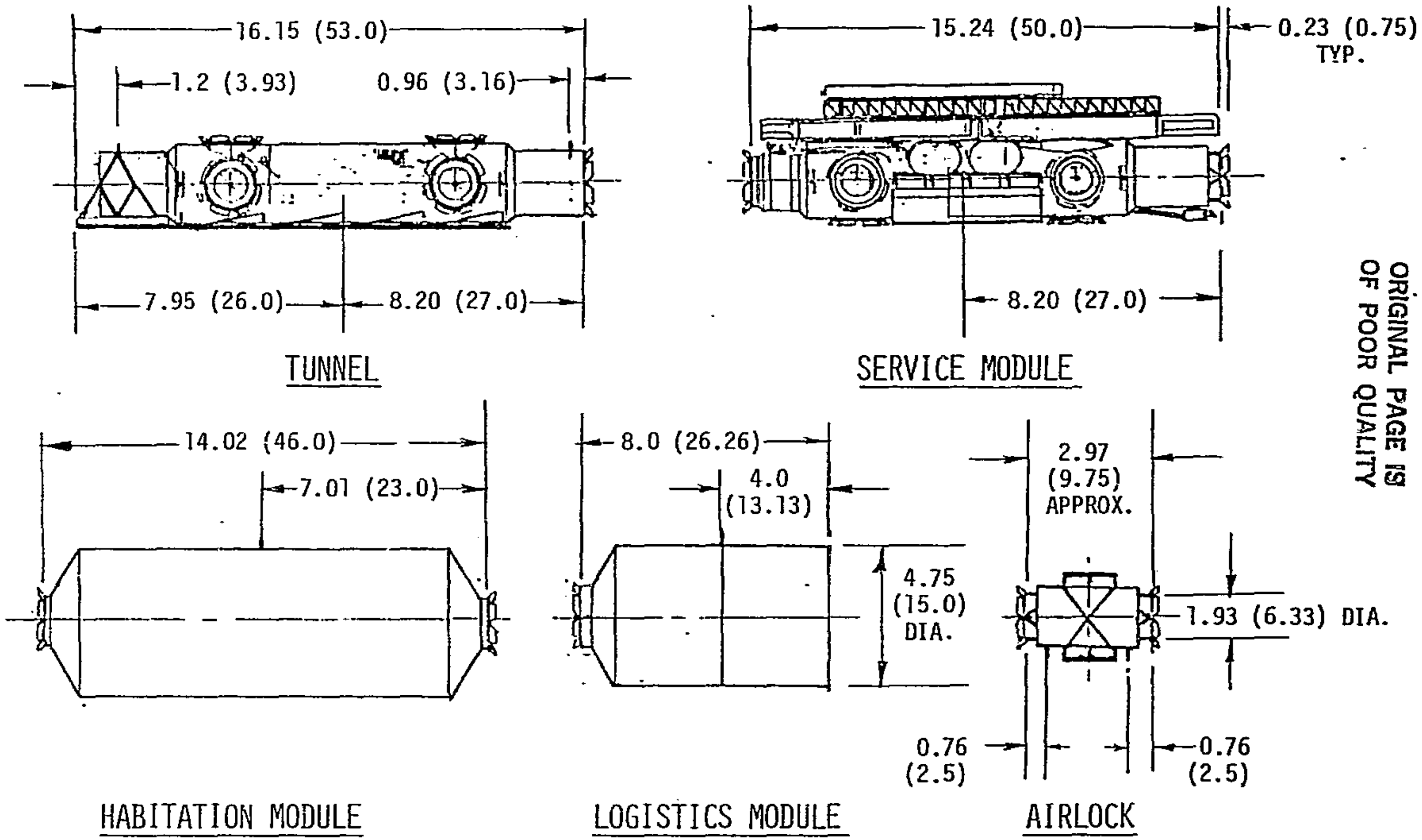
SOC ASSEMBLY - CONCEPT B
FLIGHT 6



GRAPLE FIXTURE LOCATIONS (CONCEPT B)

Grapple fixtures were located on each of the modules of Concept B to form the basis for computing their initial and final coordinates during the assembly operations. The locations were selected to be near the y-z plane of the geometric center except where it was impractical as in the case of the tunnel and the airlock.

GRAPPLE FIXTURE LOCATIONS (CONCEPT B)



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UNITS: METERS (FEET)

END EFFECTOR LOCATIONS
SOC ASSEMBLY - CONCEPT B

The initial and final RMS end effector coordinates for Concept B were computed and inputted into the "RMS" computer program. The resulting data points are listed on the opposite chart.

END EFFECTOR LOCATIONS
SOC ASSEMBLY CONCEPT B

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FLIGHT NO.	ITEM/ PAYLOAD	INITIAL RMS END EFFECTOR COORDINATES						FINAL RMS END EFFECTOR COORDINATES					
					WRIST ATTITUDE						WRIST ATTITUDE		
		X_0	Y_0	Z_0	P	Y	R	X_0	Y_0	Z_0	P	Y	R
1B/C	SM-1	966	+115	527	-31	-90	0	621	-47	838	0	-90	0
2A/B	SOC	483	-47	577	0	-90	0	394	+180	569	0	-90	0
2C/D	HM-1	1004	+95	589	-31	-90	0	532	+137	907	0	-90	0
2E/F	SOC	394	+180	569	0	-90	0	483	-47	577	0	-90	0
3A/B	AL-1	785	0	438	-90	0	0	621	+92	938	+90	0	0
3C	LM	1129	+95	589	-31	-90	0	711	-219	700	0	-180	0
3D	SOC	621	-47	838	0	-90	0	679	+242	830	0	-90	0
3E	AL-2	922	0	438	-90	0	0	679	-449	749	+105	+15	0
3F	SOC	679	+242	830	0	-90	0	621	-47	838	0	-90	0
4A/B	SOC	621	-47	838	0	-90	0	379	+126	738	0	-90	0
4B/C	SM-2	966	+115	527	-31	-90	0	933	+173	691	+90	0	0
4D	SOC	379	+126	738	0	-90	0	621	-47	838	0	-90	0
5A/B	SOC	621	-47	838	0	-90	0	531	+270	618	0	-90	0
5C	AL-2	531	-511	649	-90	+30	0	569	+247	809	-90	+90	0
5D	HM-2	1004	+95	589	-31	-90	0	531	-21	666	+90	0	0
5E	SOC	531	+270	618	0	-90	0	621	-47	838	0	-90	0
6A/B	SOC	621	-47	838	0	-90	0	531	+181	830	0	-90	0
6C	DM(TM)	700	+157	555	-90	0	0	531	-389	753	-4	+90	0
6D	SOC	621	-47	838	0	-90	0	531	+181	830	0	-90	0
6E	DM(TM)	531	-433	825	+4	+90	0	531	-401	821	0	+90	0
6F	SOC	531	+181	830	0	-90	0	621	-47	838	0	-90	0

RMS JOINT ANGLES
SOC ASSEMBLY - CONCEPT B

The results of the "RMS" computer program for Concept B are summarized on the opposite chart. It indicates similar results to that of Concept A, i.e., all the joint angle readings are below the max limits. However, there are two conditions where the readings exceed the desired range as indicate. There is a high level of confidence that these conditions can be improved or eliminated with further iterations on th "RMS" computer program.

RMS JOINT ANGLES, SOC ASSEMBLY—CONCEPT B

RMS JOINT (MAXIMUM LIMIT) / MODULE	SY (-177.4 TO 177.4)		SP (0.6 TO 142.4)		EP (-0.4 TO -157.6)		WP (-116.4 TO 116.4)		WY (-116.6 TO 116.6)		WR (-442 TO 442)	
	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL	INITIAL	FINAL
2A/B (SOC)	-166.17	-137.71	106.46	56.96	-129.75	-93.04	-32.66	8.36	66.27	44.22	0	0
2C/D (HM-1)	-58.55	-97.45	96.10	86.81	-123.75	-103.44	-27.21	-0.77	-19.39	-37.93	0	0
2E/F (SOC)	-166.17	-137.71	106.46	56.96	-129.75	-93.04	-32.66	8.36	66.27	44.22	0	0
3A/B (A/L-1)	-48.29	-88.61	92.06	71.48	-146.58	-47.83	-50.27	48.20	12.82	-45.45	0	0
3C (LM)	-33.22	49.81	59.44	132.57	-78.41	-114.79	-48.49	59.56	-33.36	76.01*	0	0
3E (A/L-2)	-26.02	90.11	71.10	91.71	-120.44	-74.47	-49.48	107.24	17.44	0.06	0	0
3F (SOC)	-113.36	-90.07	116.06	64.27	-85.24	-55.60	-51.89	-28.14	21.95	0.07	0	0
4A/B (SOC	-113.36	-138.56	116.06	70.39	-85.24	-81.64	-51.89	-16.88	21.95	44.97	0	0
4B/C (SM-2)	-35.15	-49.80	64.01	47.42	-100.40	-81.93	-26.21	109.40	-31.35	-12.43	0	0
5A/B (SOC)	-113.36	-112.37	116.06	58.09	-85.24	-91.35	-51.89	12.33	21.95	21.02	0	0
5C (A/L-2)	124.91	-118.01	85.53	43.63	-49.72	-50.64	19.16	3.91	-21.83	72.82*	0	0
5D (HM-2)	-32.10	-132.10	64.21	94.49	-85.45	-130.22	-45.09	111.03	-32.62	12.92	0	0
6A/B (SOC)	-113.36	-113.13	116.06	70.54	-85.24	-59.85	-51.89	-31.73	21.95	21.73	0	0
6C (TM)	-86.16	145.45	72.89	105.06	-107.36	-69.72	-74.96	-3.39	1.28	-50.93	0	0

(*) JOINT ANGLES EXCEEDING DESIRED RANGE (EP > 40°; WY < ±60°)

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COMPARISON OF SOC ASSEMBLY CONCEPTS

Several parameters of both assembly concepts were selected for comparing the SOC assembly concepts that were ivestigated. The selected parameters are listed on the opposite and most are self explanatory. However, those with the most significant difference require further comment.

The service module of Concept B is considerably longer than that of Concept A and that difference is the major cause for the increase in the grappling, transfer and berthing operations. In otherwords, the length of the service module is a direct contributor to the number of berthing operations during SOC assembly. This does not imply that the longer module should not be adopted for design. A factor in that decision is the trade of benefits accrued from the increased space the longer module provides against the increase in assembly time that the longer module requires.

Two ports on Concept B and two ports on Concept A require docking increments of 90° and 180°, respectively, with the orbiter docking module. The provision of system interfaces through the docking increments of 90° are required for each of these systems. The problem can be avoided if only a structural interface increment of 90° is required and the other system interfaces can await reorientation of the orbiter after completion of the assembly operations.

COMPARISON OF SOC ASSEMBLY CONCEPTS

		A	B
NO. OF FLIGHTS REQUIRED FOR ASSEMBLY		6	6
NO. OF MODULES		7	8
LENGTH OF MODULES, M (ft)	SERVICE MODULE	12.19 (40)	15.24 (50)
	HABITATION MODULE	14.02 (46)	14.02 (46)
	TUNNEL (DOCKING) MOD.	7.87 (26)	16.15 (53)
FLIGHTS REQUIRING HPA		1	5
SOC PORTS INTERFACING WITH	ORBITER DM	3	3
	HPA	2	4
DOCKING OPERATIONS		6	6
GRAPPLING, TRANSFER & BERTHING OPERATIONS		10	20
DISASSEMBLY OPERATIONS		0	1
SOC PORTS REQUIRING DOCKING INCREMENTS OF	90^0	0	2
	180^0	2	0
DEVIATIONS FROM RMS JOINT ANGLES	DESIRED LIMITS	5	2
	MAX LIMITS	0	0

SOC ASSEMBLY IMPLICATIONS

The major implications of the assembly procedures of both SOC assembly concepts are listed in the next two charts. The last item on the opposite chart and the last two items on the folowing chart need further comment.

As a consequence of the assembly procedures of both assembly concepts, it was found necessary to stow service module no. 1 and service module no. 2 in the orbiter payload bay differently. For service module no. 1, the port closest to the base joint of the solar aray boom is pointed aft, whereas, for service module no. 2, it is pointed forward. If the stowed orientations of both service modules are the same, then the RMS trajectory that is required to translate and orient one of the service modules to its assembled position would be quite difficult and time consuming. The different stowage arrangement resolved that issue even though it introduced the requirement for different interfaces with the orbiter. The difference in orbiter interfaces can be considerably minimized and consequently, it is prefereable to imposing a difficult maneuver on the part of the RMS.

Changes to the RMS control software are needed to enable the RMS to maneuver any part of the SOC assembly with a mass of over 65,000 lbs. In a brief series of simulations during the initial SOC/Shuttle Interactin Study, it was found that the RMS was unable to berth the SOC assembly to the orbiter docking port without software changes.

If the orbiter is required to dock to the SOC in other than its normal orientation then changes to its approach control would be required. The issues that are introduced by such an approach are significant for a docking orientation of 90° to normal, especially plume impingement on the SOC solar panels.

SOC ASSEMBLY IMPLICATIONS

- 3 SOC PORTS INTERFACE WITH ORBITER DM
- 2 SOC PORTS INTERFACE WITH THE HPA (CONCEPT B-4)
- REQUIRED ASSEMBLY TOOLS: RMS, HPA & PIDA
- ONLY ONE SEPARATION/REDOCKING OPERATION IS REQUIRED
- GRAPPLE FIXTURE CAN BE LOCATED ON Y-Z PLANE OF THE CENTER OF MASS OF EACH MODULE EXCEPT TM
- SUFFICIENT CLEARANCES ARE INDICATED FOR ALL ASSEMBLY OPERATIONS
- FIVE OPERATIONS EXCEED DESIRED RMS JOINT LIMITS. NONE EXCEED MAXIMUM LIMITS (CONCEPT B-2)
- SERVICE MODULES MAY REQUIRE DIFFERENT STOWAGE ARRANGEMENTS IN PAYLOAD BAY

SOC ASSEMBLY IMPLICATIONS (CONT)

- ONLY TM & LM ARE COMBINED IN ONE SHUTTLE FLIGHT IN CONCEPT A & LM, A/L-1 & A/L-2 IN CONCEPT B. ALL OTHERS REQUIRE ONE FLIGHT EACH

- SOC ASSEMBLY MAY
  - DRIVE HPA DESIGN
  - REQUIRE RMS CONTROL SOFTWARE CHANGES
  - REQUIRE CHANGES IN ORBITER APPROACH CONTROL

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EXECUTIVE SUMMARY

SHUTTLE FLEET UTILIZATION & PROGRAMMATICS

SOC ASSEMBLY OPERATIONS

FLIGHT SUPPORT FACILITY

SHUTTLE SYSTEM PROPELLANT SCAVENGING

CLOSING REMARKS

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C-3

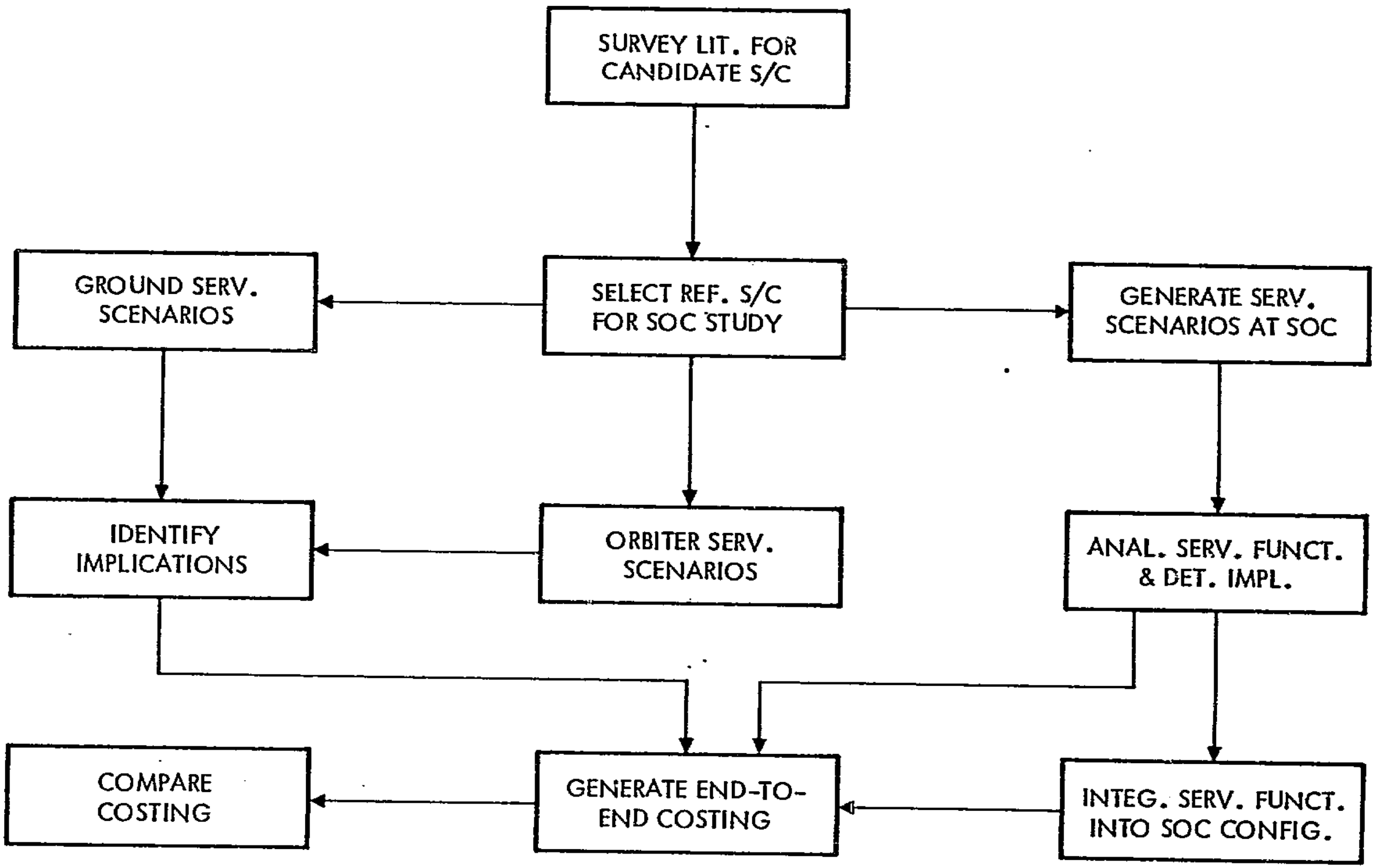
TASK 4 -- FLIGHT SUPPORT FACILITY
OBJECTIVES

COMPARE SERVICING/CHECKOUT LOGIC & COSTS OF SERVICING FREE FLYERS AT THE SOC FLIGHT SUPPORT FACILITY (FSF), ON THE GROUND & FROM THE ORBITER

TASK 4 - FLIGHT SUPPORT FACILITY APPROACH

To accomplish the objectives that are stated on the previous chart, the approach was to select reference spacecraft to represent the type that require servicing in space and analyze their servicing requirements. From the analysis, implications to the SOC, the orbiter and the reference spacecraft were determined. Furthermore, the analysis served as a basis for estimating servicing manpower and, along with the implications, generating end to end costing for final comparison.

TASK 4 - FLIGHT SUPPORT FACILITY APPROACH



TASK 4 SUMMARY

Study results that were presented during the midterm briefing are indicated. The emphasis in this final presentation was on an update of the servicing manpower estimates and the generation of cost estimates and their comparison.

TASK 4 SUMMARY

MIDTERM ACCOMPLISHMENTS

- SELECTED 3 REPRESENTATIVE SPACECRAFT FOR SERVICING & COST ESTIMATES
- GENERATED & ANALYZED 6 SERVICING SCENARIOS & DETERMINED THEIR IMPLICATIONS
- GENERATED PRELIMINARY MANHOUR ESTIMATES

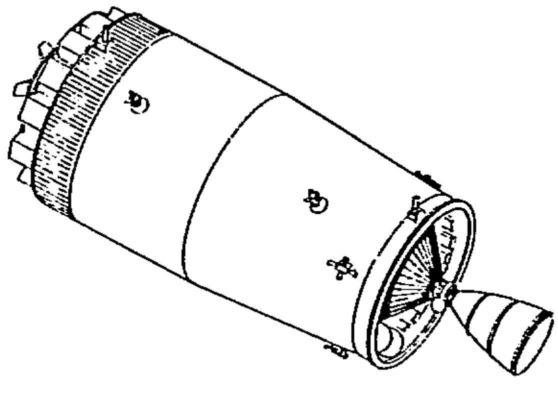
FINAL PRESENTATION

- UPDATE OF MANHOUR ESTIMATES
    - ASSUMPTIONS & DATA SOURCES
    - ANALYSIS & RESULTS
- GENERATION & COMPARISON OF SERVICING COST ESTIMATES
    - HARDWARE & LABOR COSTS
    - COMPARISON RESULTS

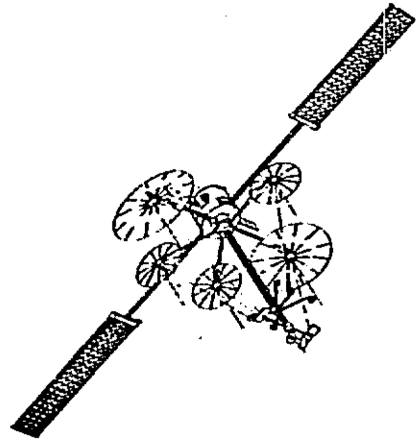
REPRESENTATIVE SPACECRAFT

From a candidate list of spacecraft, three were selected for analysis and to drive out the servicing provisions that are required on th SOC Flight Support Facility. These three spacecraft, the OTV, a Communication Satellite and a Space Processing Facility, require a wide spectrum of servicing needs that are applicable to this study. In addition, six servicing scenarios, two for each representative spacecraft, were selected for analysis and final comparison as shown on the opposite chart.

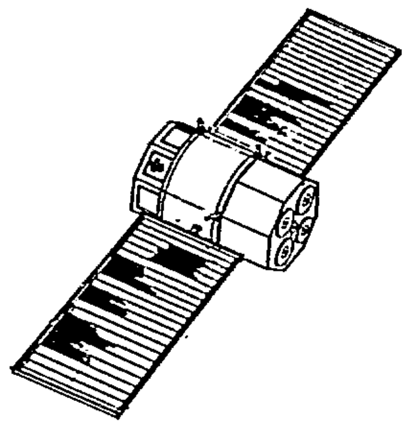
REPRESENTATIVE SPACECRAFTS



OTV



COMMUNICATION SATELLITE



SPACE PROCESSING FACILITY

- FEATURES SIGNIFICANT TO SERVICING
  - LOADING OF FLUIDS
    - CRYOGENICS - LO_2, LH_2
    - NON-CRYOGENICS - He, GN_2, HYDRAZINE
  - MODULE & COMPONENT EXCHANGE OPS
  - EXTENSIVE DEPLOYMENT & C/O OPS
  - FREQUENT REVISITS
  - SMALL TO LARGE S/C

S/C	GROUND SERVICING	ORBITER SERVICING	SOC SERVICING
OTV	✓	N/A	✓
COMM SAT	N/A	✓ INITIAL ASSY & LAUNCH TO GEO	✓ INITIAL ASSY & LAUNCH TO GEO
SPACE PROCESSING FACILITY	N/A	✓	✓

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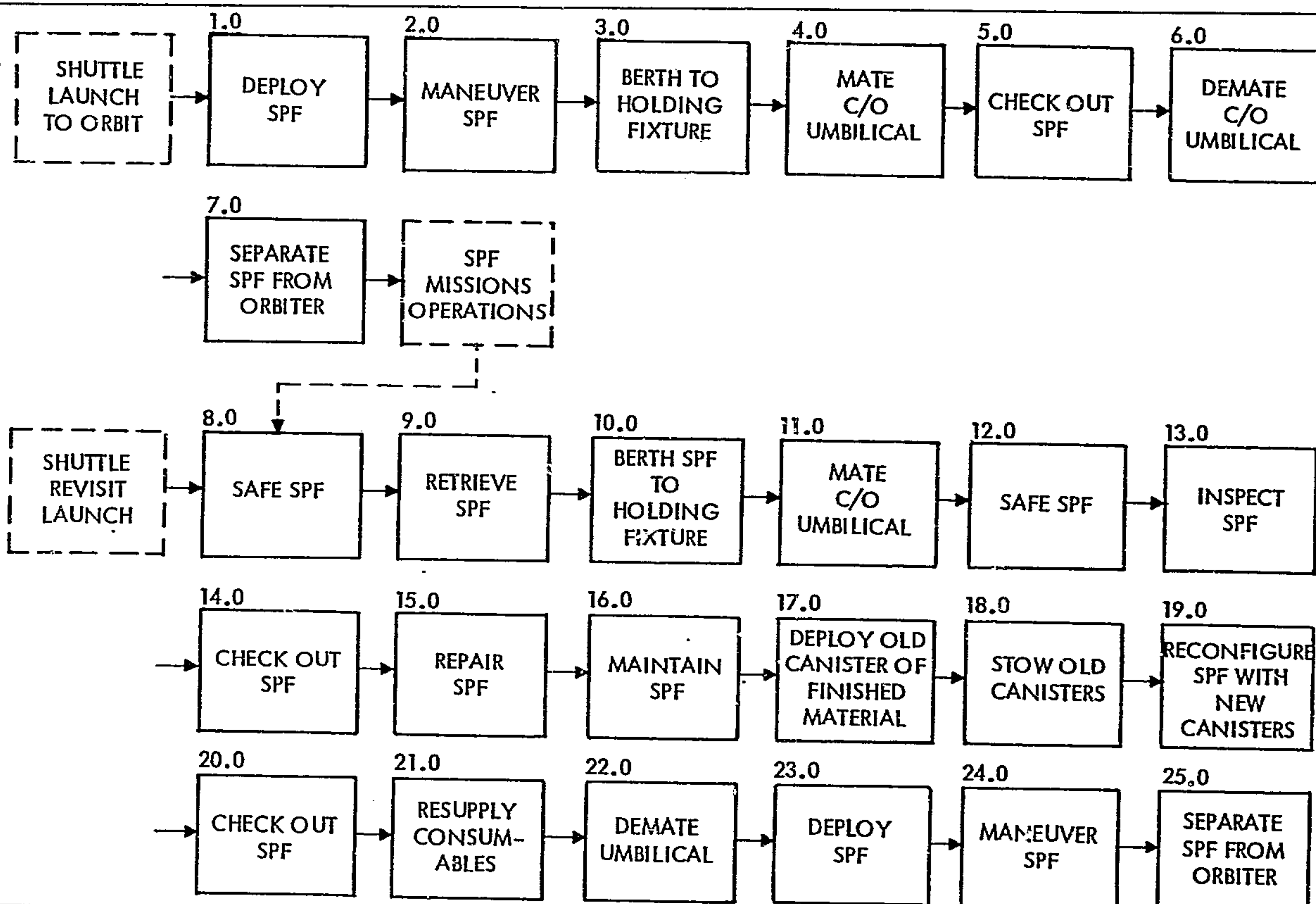
SPACE PROCESSING FACILITY - ORBITER SERVICING

For each of the six servicing scenarios, a flow chart was generated as shown in the opposite typical chart for the orbiter servicing of the Space Processing Facility. It includes the major activities that are needed to service the spacecraft in a feasible sequence. It is not implied that this is the best sequence. It is just one feasible sequence that served the purposes of the analysis.

SPACE PROCESSING FACILITY -- ORBITER SERVICING



SPF - ORBITER SERVICING IMPLICATIONS

The analysis of each servicing scenario enabled the identification of the major provisions and equipment that are needed on th SOC Flight Support Facility to perform the servicing operations. A typical summary of the required service provisions and equipment is shown on the cpposite chart. It should be noted that all of th spacecraft implications and most of the servicing base implications were not considered in the costing analysis. Only those implications that are peculiar to the servicing scenario, such as those indicated by an asterisk, were considered. Other servicing base equipment that are expected to be there for other mission scenarios were excluded.

SPF -- ORBITER SERVICING IMPLICATIONS

SUMMARY OF REQUIRED SERVICE PROVISIONS & EQUIPMENT

SPF	ORBITER
• GRAPPLE FIXTURE	• STANDARD ORBITER PLUS
• PIDA HEAD FITTINGS	• SCUFF PLATES
	• HPA
• SPF-ORBITER SYSTEM INTERFACE	*• SPF-ORBITER UMBILICAL
• MODULE LATCHING & RELEASE MECHANISM	*• SPFE
• EXPERIMENT CANISTER LATCHING & RELEASE MECHANISM	*• MODULE & CANISTER STORAGE & RETRIEVAL SYSTEM
	• MMU
• REPLACEABLE MODULE & CANISTER DESIGN	• COMMUNICATION & DATA LINK WITH SPF & ITS GROUND OCC
• COMMUNICATION & DATA LINK WITH ORBITER & GROUND OCC	*• SPF CONTROL & MONITOR STATION

ASSUMPTIONS FOR TIMELINE/MANHOUR ESTIMATION - OTV

Estimates were made of the man-hours required to perform the servicing functions. These were based on a generated set of assumptions for each of the representative spacecraft. This particular chart shows a summary of the OTV assumptions and their application to any of the two scenarios involved or both. For the OTV, two assumptions that influenced the results significantly should be noted. The ground based OTV is designed for ground servicing and the space based OTV is designed for servicing in space. What that means is that the ground based OTV is designed to be launched in the fueled condition. In other words, it is a weight sensitive conventional design. The space based OTV is launched in the unfueled condition and it is designed for easy accessibility and modular replacements of parts and components. The significance of this difference will be more evident in later charts.

ASSUMPTIONS FOR TIMELINE/MANHOUR ESTIMATION -- OTV

ASSUMPTION	TURNAROUND	
	GROUND	SPACE
• OTV DESIGNED FOR GROUND SERVICING	✓	
• OTV TURNAROUND DOES NOT PACE TOTAL ORBITER TURNAROUND TIME OF 2 WEEKS	✓	
• ONLY ACTUAL WORK IS INCLUDED IN ESTIMATES (SLEEP, MEALS & PERSONAL TIME NOT INCLUDED)	✓	✓
• SOME POTENTIAL LEARNING IS NOT ACCOUNTED FOR (CITE, FEWER REPAIRS & IMPROVED PROCEDURES & TOOLS AFTER INITIAL FLIGHT)	✓	✓
• OTV DESIGNED FOR SPACE SERVICING		✓
• FAILURE RATES BASED ON MATURE DESIGN		✓
• REPAIRS PRIMARILY BY RMS REMOVAL/REPLACEMENT		✓
• RMS TIME ESTIMATES (SPAR & MDF)		✓
• BUILT-IN AUTOMATIC TEST PROVISIONS		✓

DATA SOURCES FOR TIMELINE/MANHOUR ESTIMATION

Another basis for the manhour estimation is the data sources that were utilized for this analysis. Unfortunately, there is no actual experience or data that could be directly applied to this task. However, there are related data, as listed on the opposite chart, that were helpful in compiling the estimates.

DATA SOURCES FOR
TIMELINE/MANHOUR ESTIMATION

• RMS OPERATIONS:	NASA - MDF TEST RESULTS SPAR ELECTRONIC SIMULATIONS
• FAILURE RATES:	SKYLAB III DATA (30 - 40 FAILURES / 1000 HOURS)
• CHECKOUT TIMES:	MILITARY AIRCRAFT EXPERIENCE
• GROUND TRANSPORT & CHECKOUT:	STAR 20 (SHUTTLE TURNAROUND ANALYSIS REPORT)
• SCHEDULED & UN-SCHEDULED REPAIR:	MILITARY AIRCRAFT EXPERIENCE. FOR OTV, 3 HRS/REPAIR ASSUMING EASILY REPLACEABLE MODULAR UNITS
• OTHER TIME ELEMENTS:	ENGINEERING JUDGMENT

TIME RATIONALE - OTV TURNAROUND AT SOC

For each of the servicing scenarios, man-hours were estimated as illustrated in the opposite typical chart for the OTV turnaround at the SOC. Each activity was analyzed separately and the resultant elapsed time, number of crewman required and the man-hours are indicated. The rationale for each estimate is also indicated. The task numbers in the first column correspond to the activity number that were assigned in the flow chart of the corresponding scenario.

TIME RATIONALE - OTV TURNAROUND AT SOC

TASK NO.	TASK DESCRIPTION	ELAPSED TIME (HR)	CREW QTY	MAN-HR	RATIONALE
1.0	RETURN OTV TO SOC (PREPARATION BY CREW)	4.0	5	20.0	PLANNING INCLUDES ALL ASSIGNED CREW; ACQUISITION & MONITORING INCLUDED
2.0	SAFE OTV (DEACTIV. MAIN ENGINE) AND PERFORM PROXIMITY MANEUVERS (STATIONKEEPING)	0.5	3	1.5	PRELIMINARY ESTIMATE
3.0	DOCK OTV TO SOC	0.5	4	2.0	SIMILAR TO ORBITER DOCKING; SAFETY-CRITICAL MANEUVER; EXTRA "EYES" REQ'D
4.0	SAFE OTV (DEACTIVATE ATTITUDE CONTROL SYSTEM)	0.3	4	1.2	MULTIPLE CREW AT READINESS
5.0	MANEUVER OTV TO FSF (USING MANIP.)	0.5	5	2.5	RMS OPERATOR, SOC CDR, FSF OPERATOR, OTV DIRECTOR OBSERVER
6.0	MATE CHECKOUT UMBILICALS	0.5	5	2.5	RMS OPERATION, SIMILAR TO SPAR DATA
7.0	(a) SAFE OTV (POWER, FLUIDS) (b) INSPECT OTV (RMS TV CAMERA)	0.5 2.0	4 4	2.0 8.0	} ENGR. ESTIMATES
8.0	TEST OTV (ELECTRONICS & MECH. ACTUATORS–VERIFY ONBOARD TEST EQUIPMENT DATA)	1.0	4	4.0	INCLUDES GROUND COMMUNICATIONS SPECIAL PROGRAMS
9.0	PERFORM SCHEDULED MAINTENANCE	24.0	3	72.0	TWO MODULES REPLACED @ 2 HR EACH SERIALLY

TIME RATIONALE - OTV TURNAROUND AT SOC

The oposite chart is a continuation of the previous chart and it indicates the total estimated servicing man-hours that are required for the subject scenario.

TIME RATIONALE - OTV TURNAROUND AT SOC

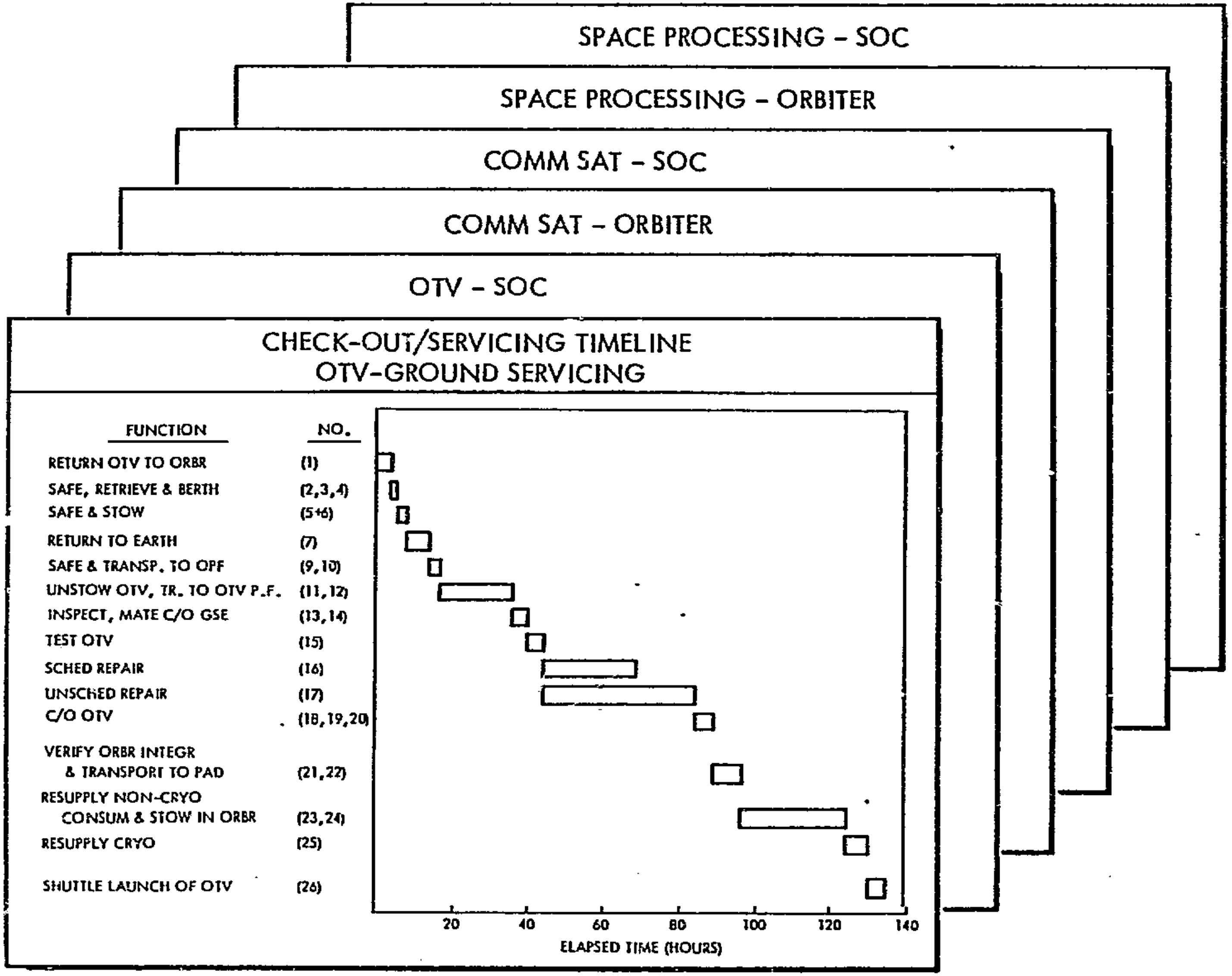
TASK NO.	TASK DESCRIPTION	ELAPSED TIME (HR)	CREW QTY	MAN-HR	RATIONALE
10.0	PERFORM UNSCHEDULED (CORRECTIVE) MAINT. REPAIR (RMS REPLACEMENT OF LRU'S)	16.0	3	48.0	3 HR PER FAILURE, 2 FAILURES IN 50 HR (EST.); MATURE, RELIABLE DESIGN
11.0	MAINTAIN OTV (NOT USED—SEE 9.0)	—	—	—	DUPLICATION—NOT USED
12.0	CHECKOUT OTV	1.5	4	6	0.75 HR PER FAILURE, 2 FAILURES IN 50 HR (EST.)
13.0	RESUPPLY CONSUMABLES	6.0	4	24	PRELIMINARY ESTIMATE, ASSUMES ADEQUATE LINE SIZE
	TOTAL	57.3	3.75 AVG*	193.7	

$$\text{*CALCULATED BY: } \frac{\text{TOTAL MAN-HOURS}}{\text{TOTAL ELAPSED TIME}}$$

TIMELINE ANALYSIS CHARTS

From these estimates, timeline bar charts were prepared to make the scenarios more comparable. For the most part, the activities were conducted serially. The most notable exception is shown here for the OTV ground servicing where the scheduled and unscheduled repair activity were performed in parallel.

TIMELINE ANALYSIS CHARTS



CHECKOUT/SERVICING MANHOURS SUMMARY

The results of these bar charts are summarized in the opposite chart. It must be emphasized that there figures indicate actual work. They do not include, sleep, meal or personal time and they will differ if the number of work shifts and crewmen are increased or decreased. The estimates for the two COMMSAT scenarios and the two Space Processing scenarios are not significantly different. However those for the OTV, the difference is very significant. The causes of this difference are presented on the next few charts.

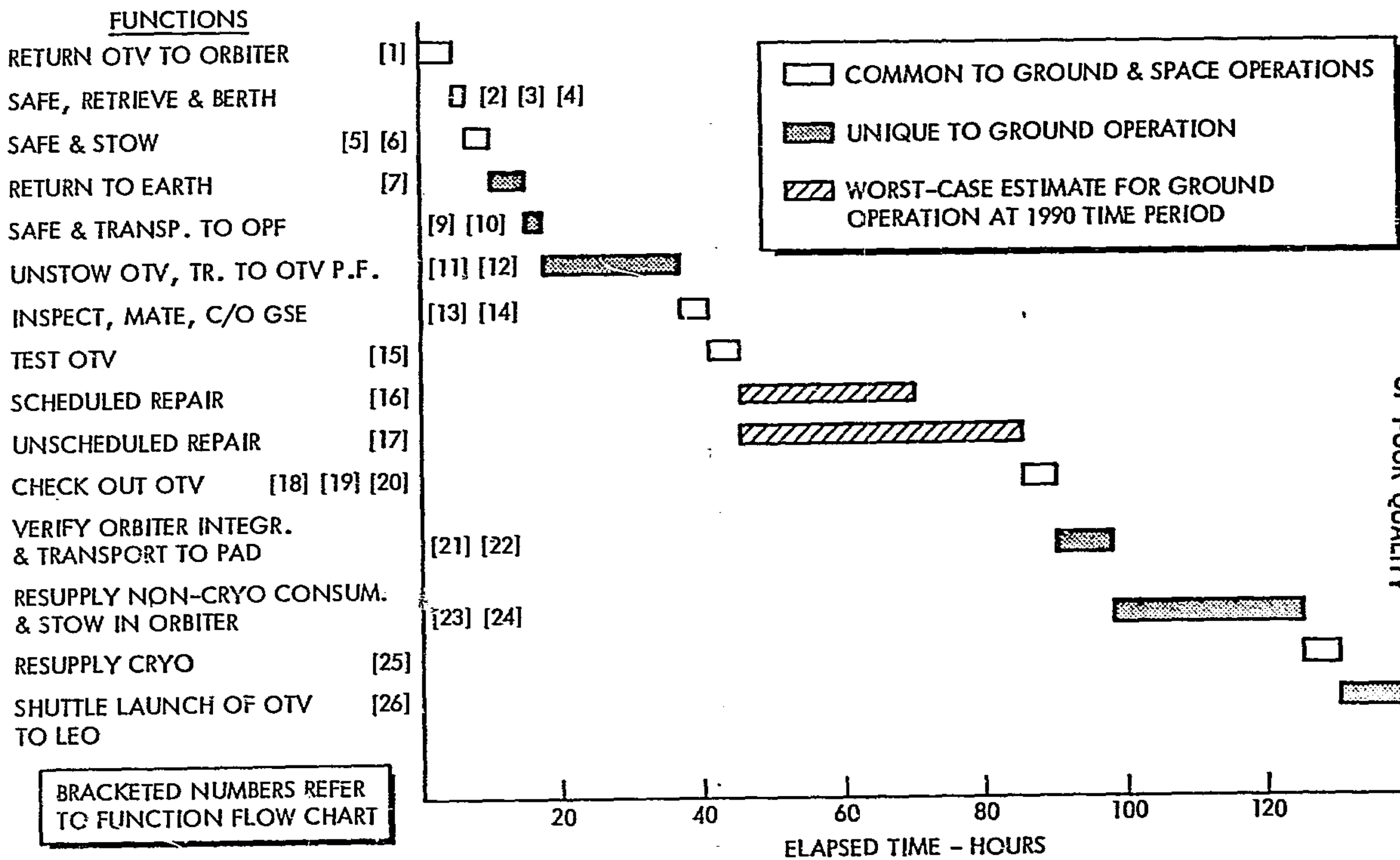
CHECKOUT / SERVICING MAN-HOURS SUMMARY

LOCATION	ELAPSED TIME	MAN-HOURS	NO. CREW	
			RANGE	AVG
OTV-GROUND	140.0	600.0	3 - 6	4.3
OTV-SOC	57.3	193.7	3 - 5	3.8
COMM SAT-ORBITER	50.8	164.8	2 - 4	2.4
COMM SAT-SOC	61.0	199.6	2 - 5	2.6
SPACE PROCESSING-ORBITER	27.5	106.0	2 - 4	3.5
SPACE PROCESSING-SOC	29.6	103.4	3 - 4	3.5

TIMELINE ANALYSIS OF OTV GROUND TURNAROUND SHOWING UNIQUE DIFFERENCES FROM SPACE OPERATIONS

The opposite bar chart represents the timeline of the OTV ground turnaround. The bars representing activities or functions that are common with space operations are left blank. The bars representing activities that are unique to ground operations or differ considerably in timeline from equivalent space operations are shaded. A more detailed look at the activities that are unique to ground operations and their equivalent space operations are presented on the next chart.

TIMELINE ANALYSIS OF OTV GROUND TURNAROUND SHOWING UNIQUE DIFFERENCES FROM SPACE OPERATIONS



BRACKETED NUMBERS REFER TO FUNCTION FLOW CHART

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OTV TURNAROUND OPERATIONS COMPARISONS
(GROUND VS SOC TURNAROUND)

The signigicant operational differences between ground and SOC turnaround of the OTV are shown in the opposite chart. It is noted that ground activities 7, 9, 10, 11, 12, 21 and 22 are not applicable to space operations. Of the remaining activities, the equivalent space oprations consume less time than ground operations.

OTV TURNAROUND OPERATIONS COMPARISONS (GROUND VS. SOC TURNAROUND)

	GROUND	SOC
ELAPSED TIME, HR	140	57.3
MAN-HOURS	600	193.7

SIGNIFICANT OPERATIONS DIFFERENCES

	GROUND		SOC		DIFFERENCE	
	ELAPSED TIME (HR)	MAN-HOURS	ELAPSED TIME (HR)	MAN-HOURS	ELAPSED TIME (HR)	MAN-HOURS
RETURN TO EARTH [7]	6	24	N/A	N/A	6	24
SAFE & TRANSPORT TO OPF [9] [10]	2	⊕	N/A	N/A	2	—
UNSTOW OTV, TRANSP. TO P.F. [11] [12]	20	60	N/A	N/A	20	60
SCHEDULED REPAIR [16]	24 } 40□	72	24 ◇	72 ◇	0	0
UNSCHEDULED REPAIR [17]	40 } MAX	120	16	48		72
ORBITER-OTV CHECKOUT / TRANSPORT TO PAD [21] [22]	8	48	N/A	N/A	8	48
RESUPPLY FLUIDS / STOW IN ORBITER [23] [24]	27	142	6	24	21	118
TOTAL	103	466	46	144	57	322

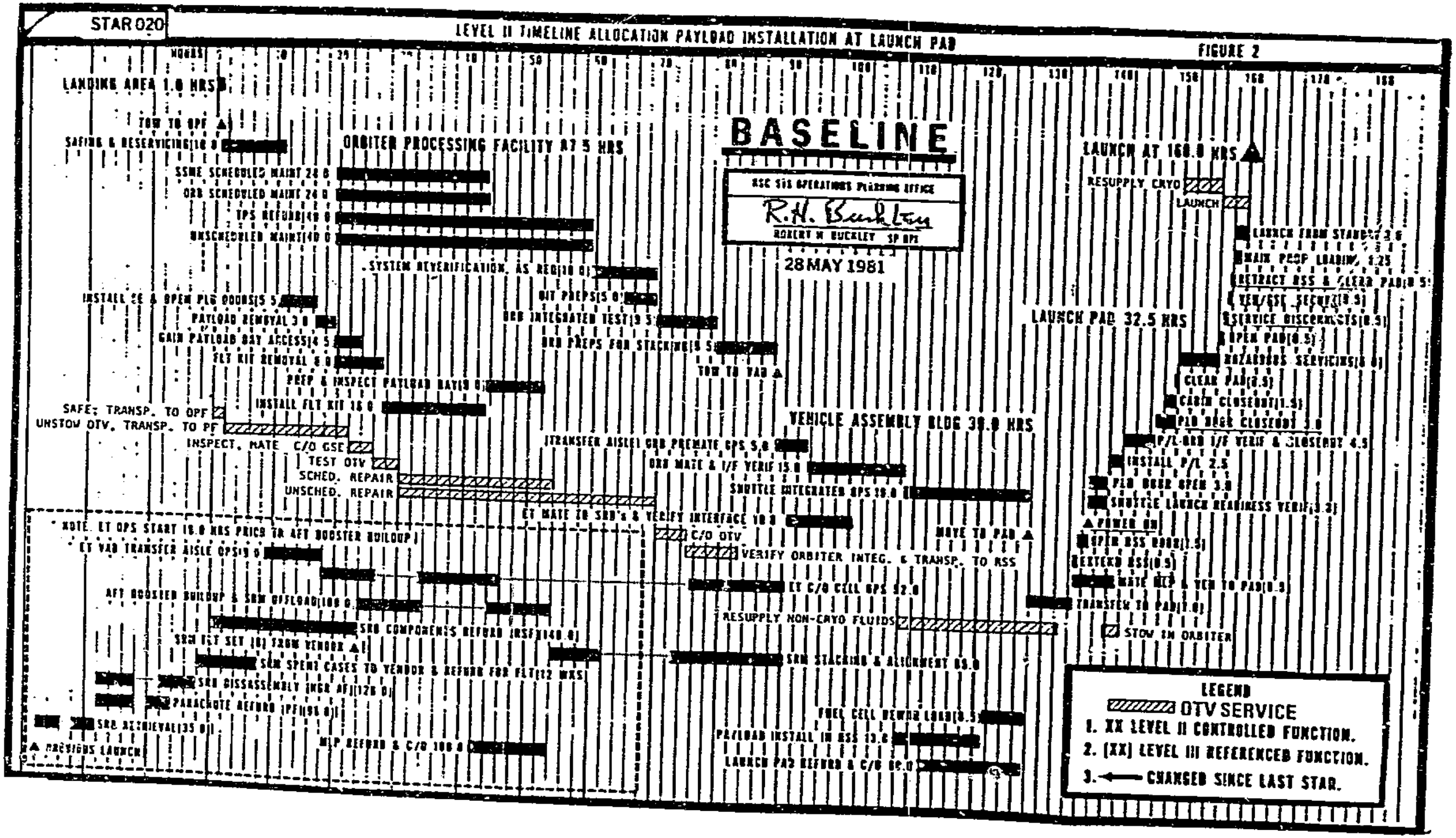
REMARKS

- ⊕ ORBITER FUNCTION—NO CREW INVOLVED WITH OTV
- □ CORRECT TWO LRU FAILURES
- ◇ BATTERIES AND FILTERS

OTV SERVICING TIMELINE

The total man-hours required for the OTV ground turnaround fit in very nicely with the orbiter turnaround activities. In the opposite chart, the OTV timeline is superimposed on the STAR 20 timeline for the orbiter. It can be seen that the OTV timeline does not impact the orbiter timeline. But the orbiter timeline impacts and restricts activities on the OTV during the period when the orbiter is on the launch pad. Timelines for the OTV scheduled and unscheduled repair activities require further investigation. As key factors in the OTV schedule and with no actual experience on which to base the estimates the confidence level in the estimates is not high. The most relevant experience which can be applied at this time is Skylab which is presented in the next chart.

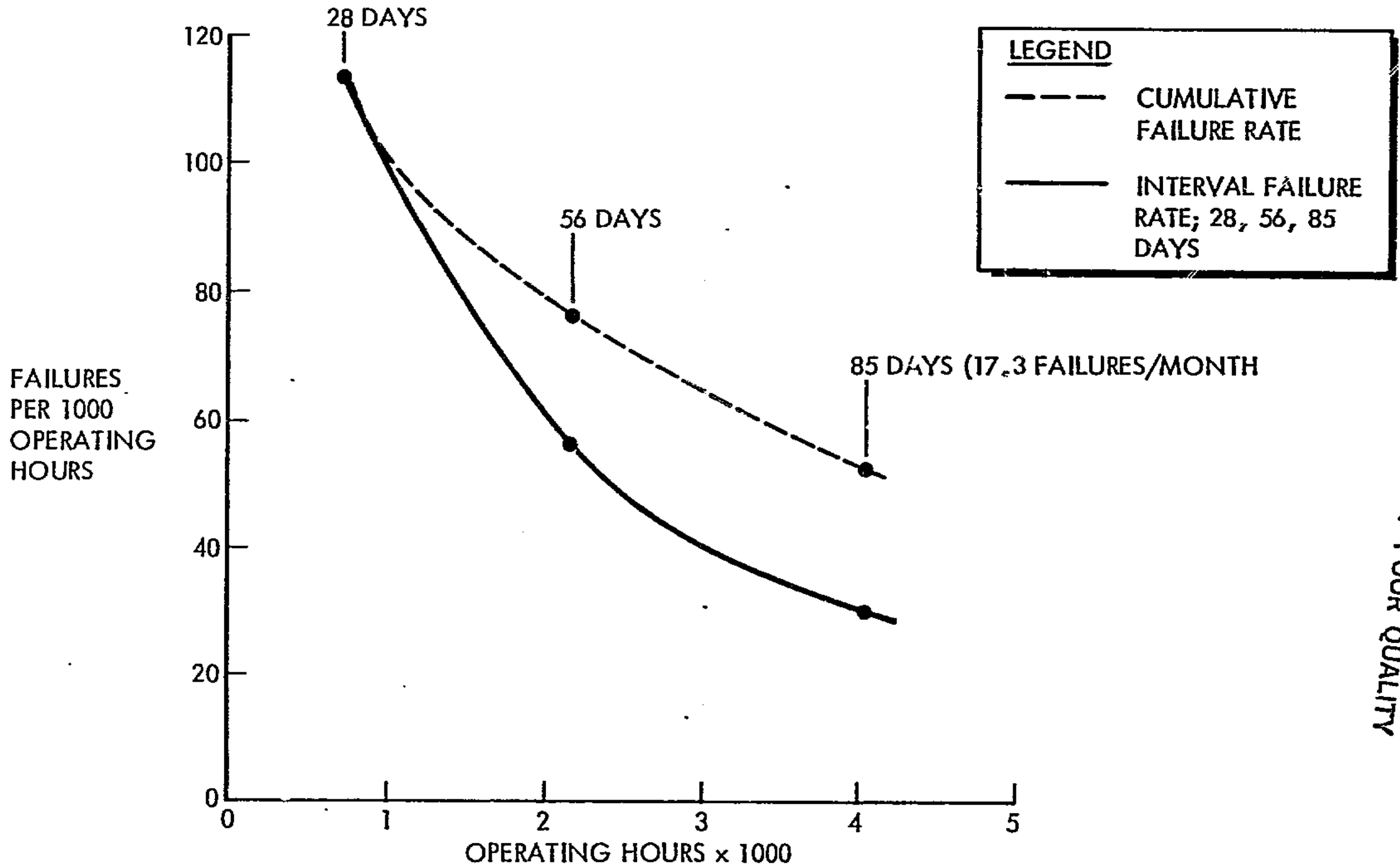
OTV SERVICING TIMELINE



SKYLAB IN-ORBIT BAILURE RATES

The most applicable data relating to scheduled and unscheduled repair in space comes from the Skylab program. The opposite chart shows the failure rates of the three Skylab missions. As experience is gained, failure rates decreased. On the third mission, failure rates are approximately one-third of those of the first mission. The lower rate was the basis for the applicable servicing activities in this task. In other words, mature designs were assumed for all the elements of the servicing analysis.

SKYLAB IN-ORBIT FAILURE RATES



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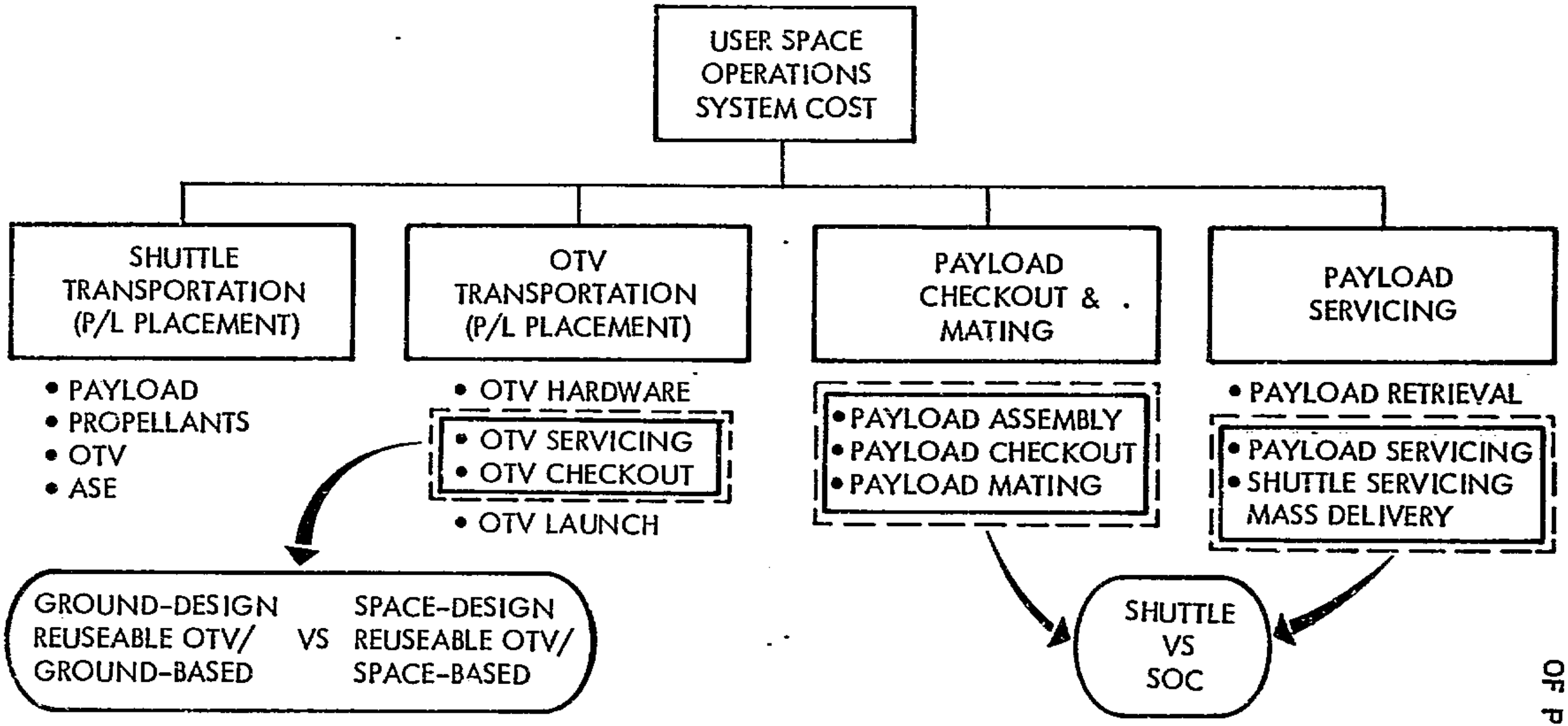
NOTE: DATA TAKEN FROM AIAA TECHNICAL PAPER 78-325, NEW DIMENSIONS IN MAN-MACHINE DESIGN, BY A. J. LOUVIERE, DATED FEB. 7-9, 1978

SERVICING COMPARISON APPROACH

The major objective of this task was to compare the servicing scenarios in terms of cost. The opposite chart presents an overview of all the cost elements of a space operations system for its user. It was not intended to investigate all the elements. Only those elements that are bounded by dashed lines were considered for the cost analysis. Furthermore, all DDT&E costs were considered as an investiment in national security and, therefore, were excluded from the cost analysis. The labor costs were based on the estimated man-hours and derived hourly charges for use of the orbiter and the SOC.

SERVICING COMPARISONS APPROACH



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GROUND RULES

- UNIT & OPERATIONS COSTS (DDT&E EXCLUDED – NATIONAL SECURITY INVESTMENT)
- COSTS IN FY 81 DOLLARS
- HARDWARE EXISTING FOR OTHER PURPOSES NOT COSTED
- LABOR COST ESTIMATES BASED ON:
  - ESTIMATED MAN-HOURS
  - DERIVED HOURLY CHARGES

SUMMARY COST COMPARISON

The opposite chart summarizes the costs for each of the six servicing scenarios. The major cost elements of each scenario are the hardware costs which do not include DDT&E costs and labor costs per servicing. It can be seen that SOC servicing costs less in each of the comparable scenarios for each of the representative spacecraft.

SUMMARY COST COMPARISON

	MILLIONS OF FY '81 $	
	GROUND SERVICING	SOC SERVICING
OTV SERVICING		
HARDWARE COST (TOTAL)	27	8.5
LABOR PER SERVICING	2.76	4.72
ORBITER FLIGHT COST PER SERVICING	3.56	-
	ORBITER SERVICING	SOC SERVICING
COMM SAT SERVICING		
HARDWARE (TOTAL)	3.5	0.3
LABOR PER SERVICING	7.34	4.48
ORBITER FLIGHT COST PER SERVICING	3.56	-
SPF SERVICING		
HARDWARE (TOTAL)	9.6	14.2
LABOR PER SERVICING	4.72	2.51
ORBITER FLIGHT COST PER SERVICING	16.1	8.73

OTV SERVICING HARDWARE COSTS IMPACT (MILLIONS OF FY'81 $)

The hardware elements that were included in the costing analysis were identified in the implications of the servicing scenarios and only those that were peculiar to the servicing scenario were included in the cost analysis. As an example, the opposite chart shows five pieces of hardware for OTV ground servicing and three for SOC servicing. Each hardware element was described and its mass estimated in terms of structures, mechanisms, electrical and electronic elements. Based on that data, costs were estimated for each piece of equipment. DTT&E costs were excluded from the cost analysis and are shown on the chart for information purposes. Similar data was generated for the COMMSAT and the SPF scenarios.

OTV SERVICING HARDWARE COST IMPACT
(MILLIONS OF FY'81 $)

OTV GROUND SERVICING

	DDT&E	TFU
• SERVICE FIXTURE WITH SERVICE CONNECTION	12.0	12.0
• UMBILICAL ARMS ON OTV SERVICE FIXTURE	4.6	7.9
• OTV FLUIDS INTERFACE ON ORBITER	2.2	2.7
• ELECTRICAL INTERFACE ON ORBITER	2.1	0.67
• OTV CONTROL AND MONITOR STATION ON ORBITER	4.7	4.1
TOTAL	25.6	27.37
TOTAL DDT&E AND PRODUCTION UNIT	52.97	

OTV-SOC SERVICING

	DDT&E	TFU
• OTV CONTROL AND MONITOR SOFTWARE	1.0	-
• EXTENDABLE NON-PROPULSIVE BOOM	0.94	0.56
• RETRACTABLE UMBILICALS	4.6	7.9
TOTAL	6.54	8.46
TOTAL DDT&E AND PRODUCTION UNIT	15.00	

BASIS FOR ORBITER SERVICE CHARGE
INCREASED INVESTMENT PROCESS

The costing for the orbiter service charge is derived on the opposite chart. It is based on the assumption of 48 Shuttle missions per year, 75% of which require a longer duration mission than the standard one-day mission as designated in te Shuttle Reimbursement Guide. If the longer duration missions are assumed to be 11 days, then 1.2 Δ orbiters need to be added to the fleet size. Based on the additional hours associated with the 1.2 orbiters, the cost of the orbiters and its support charges, an hourly orbiter service charge is derived. A four-man crew is assumed for the orbiter with each crewman working a 10-hour shift per day. A forecasted increase in the orbiter supported charge is included in the derivation.

BASIS FOR ORBITER SERVICE CHARGE
INCREASED INVESTMENT PROCESS

GROUND RULES

- REQUIREMENT FOR LAUNCH RATE DURING 90'S = 48 SHUTTLE MISSIONS/YEAR: 75 PERCENT OF MISSIONS REQUIRE LONGER DURATION . . . THIS REQUIRES PURCHASE OF ADDITIONAL ORBITERS
- STD ORBITER = 15 MISSIONS/ORB/YR AT 48/YR = 3.2 ORBITERS RQRD
- 11 DAY ORBITER = 10 MISSIONS/ORB/YR AT 48/YR = 4.8 ORBITERS RQRD

REFINEMENT		
0.75 X 4.8	(36 LONG DURATION FLTS)	= 3.6 ORBITERS RQRD
0.25 X 3.2	(12 STD FLTS)	= 0.8 ORBITERS RQRD
		4.4
	LESS STD ORB FLTS RQMTS	− 3.2
		1.2 ΔORBITER RQMTS FOR EXTRA HOURS BOUGHT

- Δ HOURS BOUGHT

  1.2 ORBITERS X 100 FLTS/ORB X 400 HRS/FLT = 48000 ΔHRS
- ΔCOST 1.2 X $\$732\overline{M}$/ORB = $878\overline{M}$
- HDWR COST PER ADDL HOUR BOUGHT = $878\overline{M} \div 48000$ HRS = $18,292/HR
- ORBITER SUPPORT CHARGE FOR ΔDAY = $0.5\overline{M}$

  PER HOUR = $0.5\overline{M} \div 40$ HRS = $12,500/HR

  ESTIMATED INCREASE = 2.1 *X 12500 = $26250/HR
- COST PER HOUR

Δ HDWR	18292
Δ SUPPORT	26250
TOTAL	$44542/HR

*FORECASTED COST INCREASE

BASIS FOR SOC CHARGE ESTIMATES

The cost of the SOC was based on Rockwell's Modular Space Station Study. The 11-year operations cost include ground operations support for logistics flights without the addition of new facilities. The operations cost do not include payload operations. The SOC charges assume only six of the eight-man SOC crew are available for the servicing operations. The other two crewmen would be committing to SOC maintenance duties.

BASIS FOR SOC CHARGE ESTIMATES

• SOC

		COST ESTIMATE (MILLIONS OF FY '81 $)
BASE		1123*
SPARES (33% FOR 11 YEARS)		374
OPERATIONS (11 YEARS)		440
STS LOGISTICS FLIGHTS		1718
ΔORBITER COST ALLOCATION		362
TOTAL SOC SPACE SEGMENT COST USED AS CHARGE BASIS		4017
NO. OF HOURS AVAILABLE FOR SERVICE		
6 MEN X 48 HOURS/WEEK X 52 WEEKS/YEAR X 11 YEARS	=	164,736
SOC CHARGE COST PER HOUR	=	$24,384

*BASED ON ROCKWELL'S MODULAR SPACE STATION STUDY

COMPARISON SUMMARY

A summary of all the timelines and cost estimates associated with the six servicing scenarios is shown on the opposite chart. The labor costs that were previously derived are for each servicing mission. Considering the number of servicing missions over an 11-year period, based on a medium mission model, and the addition of hardware costs, the user operational cost over an 11-year period is indicated in the last column. The cost advantage of the SOC servicing scenarios over the other are clearly seen.

COMPARISON SUMMARY

	EVALUATION FACTORS								
	NO. OF UNIQUE EQUIPMENT	ELAPSED TIME (HRS)	MAN-HOURS	NO. CREW	** EQUIPT COST($M)	LABOR COST($M) PER SERVICING	ORBITER FLIGHT COST ($M)	NO. OF SERVICING MISSIONS	USER 11-YEAR OPERATIONAL COST ($M)
SPACE BASED OTV	3	57.3	193.7	3-5	8.5	4.72	–	172	820
GROUND BASED OTV	5	140	600	3-6	27	2.76	3.56	331	2119
COMM-SAT-SOC	2	61.0	200	2-5	0.3	4.88	–	92	449
COMM-SAT-ORBITER	2	50.8	165	2-4	3.5	7.34	3.56	251	2739
SPF - SOC	3	29.6	103	3-4	14.2	2.51	8.73	110	1251
SPF - ORBITER	4	27.5	106	2-4	9.6	4.72	16.1	110	2300

** LESS DDT & E

EXECUTIVE SUMMARY

SHUTTLE FLEET UTILIZATION & PROGRAMMATICS

SOC ASSEMBLY OPERATIONS

FLIGHT SUPPORT FACILITY

SHUTTLE SYSTEM PROPELLANT SCAVENGING

CLOSING REMARKS

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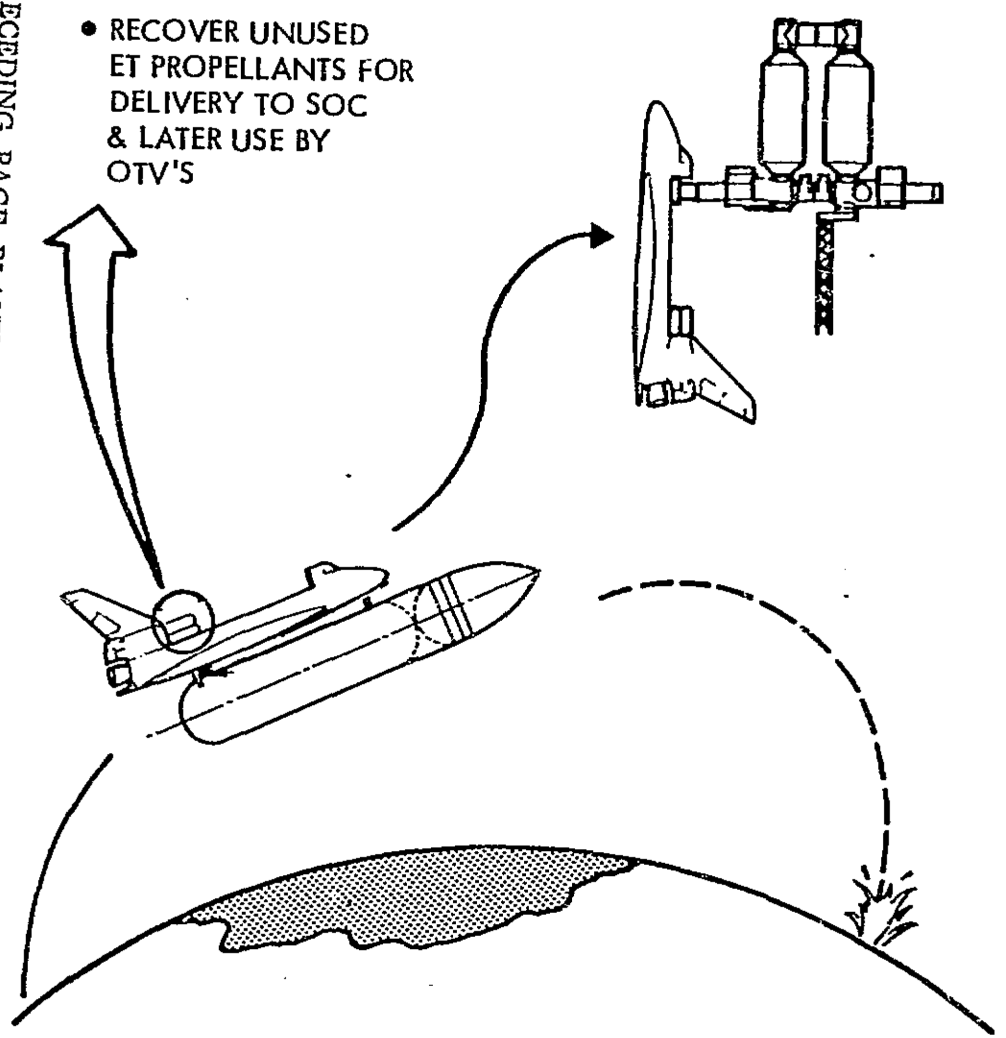
ET PROPELLANT SCAVENGING

- RECOVER UNUSED ET PROPELLANTS FOR DELIVERY TO SOC & LATER USE BY OTV'S



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ISSUES CONSIDERED

✓ ET DISPOSAL
✓ MECO TRANSIENTS
✓ ULLAGE THRUSTING OPTIONS
✓ PRESS VS PUMPED TRANSFER
✓ PAYLOAD IMPACTS
✓ TANKS & PLUMBING CONCEPTS
✓ CREW & SAFETY CONSIDERATIONS

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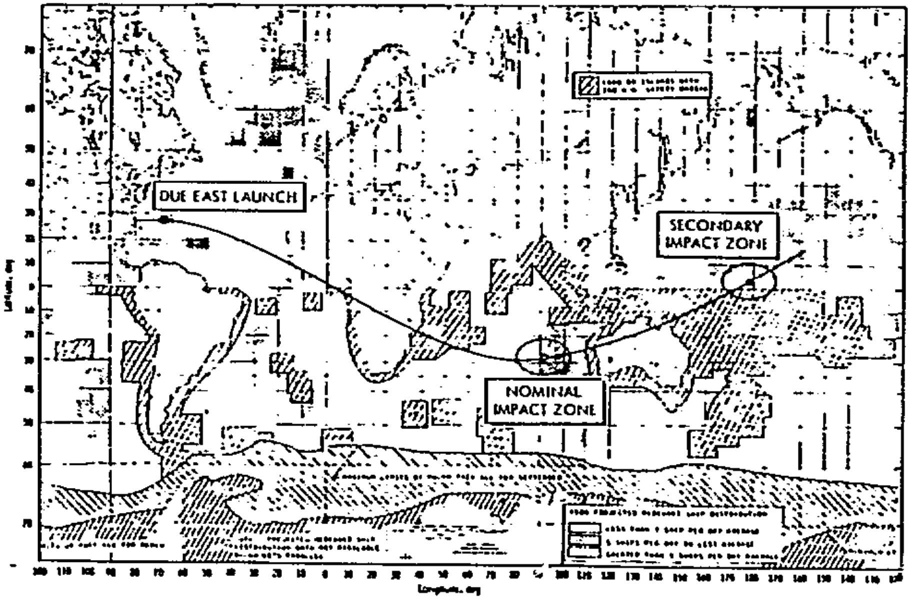
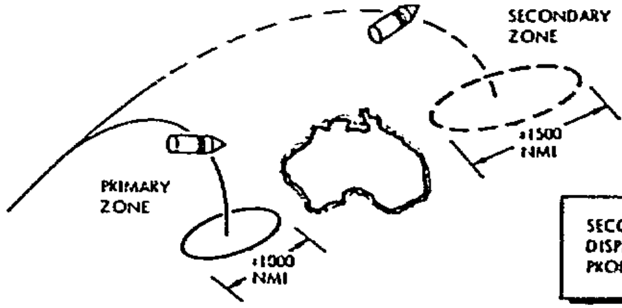
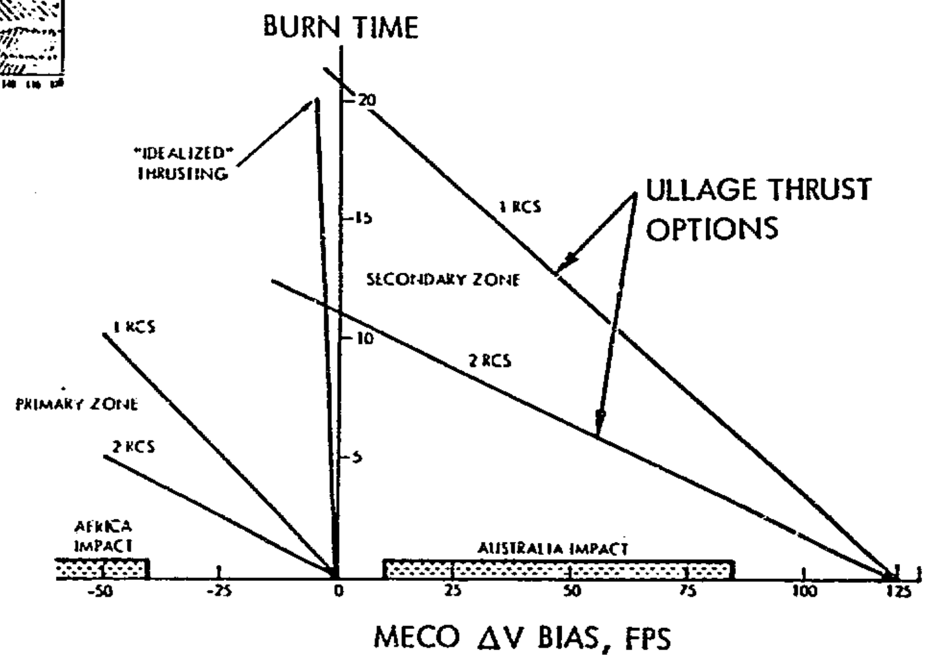
ET DISPOSAL





SECONDARY ZONE DISPERSIONS ARE PROBABLY ACCEPTABLE

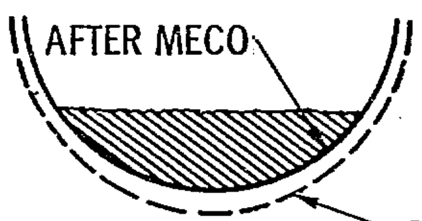
IMPACT ZONE	NUMBER OF RCS	RCS THRUST (LB)	THRUST TIME (MINUTES)	ΔR/ΔW (NM/%)	ΔR/ΔC$_A$ (NM/%)	ΔR/ΔV (NM/FPS)	ΔR/Δρ (NM/%)
SECONDARY	1	870	20.8	10	-8.8	109	-10.1
SECONDARY	2	1740	11.0	6.4	-5.8	63	-6.1
PRIMARY	1	870	5.0	2.8	-2.8	42	-3.0
PRIMARY	2	1740	5.0	2.8	-3.0	43	-3.1

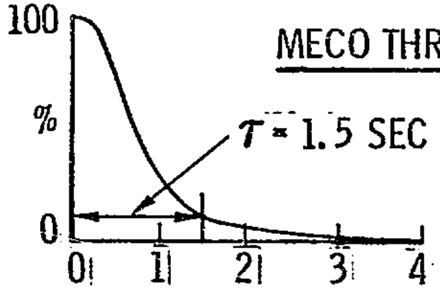


- ET IMPACT SATISFIED
- MECO CHANGES MINOR
- SHUTTLE BOOST TRAJ CONSTRAINTS ARE MET
- NEGLIGIBLE SHUTTLE P/L IMPACTS

MECO THRUST TRANSIENT EFFECTS

BULKHEAD "TWANG"



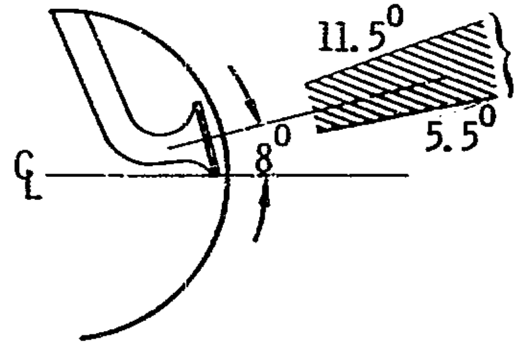


- SHUTTLE HYDRO ELASTIC MODELING AT MECO SHELL-FLUID $f_c = 26$ Hz
- $\frac{\tau}{T} = 39$
- STRUCTURAL RESPONSE

$$R = 1 + \left/ \frac{\cos \pi \frac{\tau}{T}}{\left(2\frac{\tau}{T}\right)^2 - 1} \right/ = 1.00016$$

NO "TWANG" PROBLEM ✓

RCS THRUST DIRECTION



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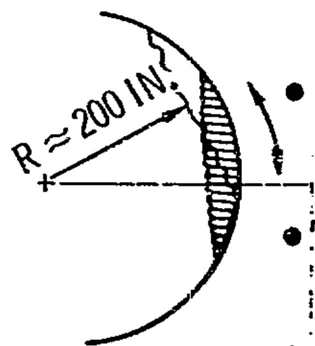


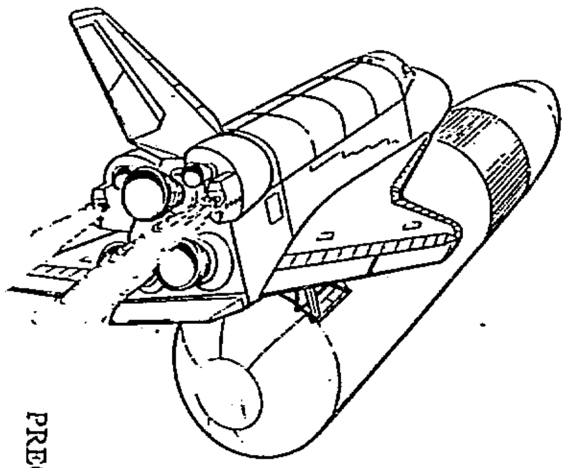
PENDULUM MOTION

- CENTERED ABOUT 10^0 RCS THRUST DIRECTION
- $T = 2\pi\sqrt{\frac{\ell}{g}} = 64.8$ SEC AT T/W = 0.0047 g's
- AMPLITUDE $R\,\theta_{MAX} \approx 16$ INCHES

VERY MILD TRANSIENT ✓

ULLAGE THRUST OPTIONS

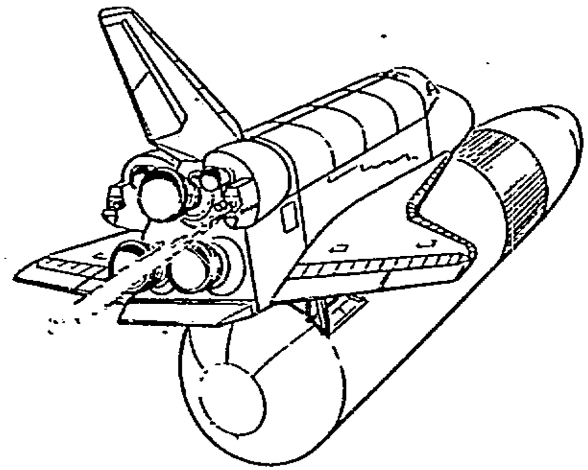
DUAL PRCS THRUSTERS



- $2 \times 870 = 1740\ lb_f$
- $T/W = 0.0047$ g's
- $\dot{w}_p \approx 414$ lb/min

- MINIMUM ORBITER IMPACT

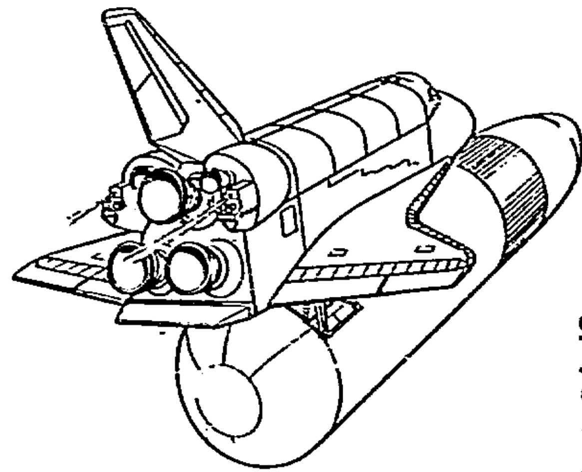
SINGLE PRCS THRUSTER



- $1 \times 870 = 870\ lb_f$
- $T/W = 0.0024$ g's
- $\dot{w}_p \approx 207$ lb/min

- ATTITUDE CONTROL SOFTWARE MOD

ADDED VERNIER THRUSTERS



- $T_{INITIAL} = 2 \times 870 = 1740\ lb_f$ (APPROX. 40 – 60 sec)
- T_{FINAL} = DRAG + 50 lb_f
- $T/W \approx 10^{-4}$ g's
- $\dot{w}_p \approx 11.5$ lb/min

- HARDWARE & SOFTWARE MODS

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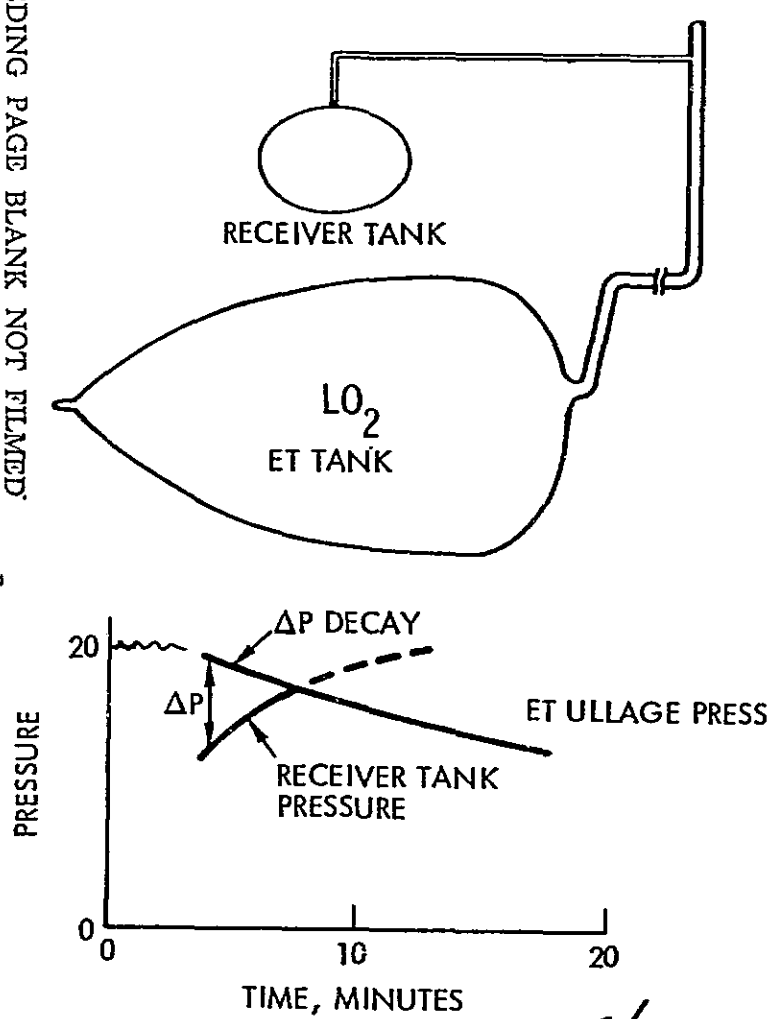
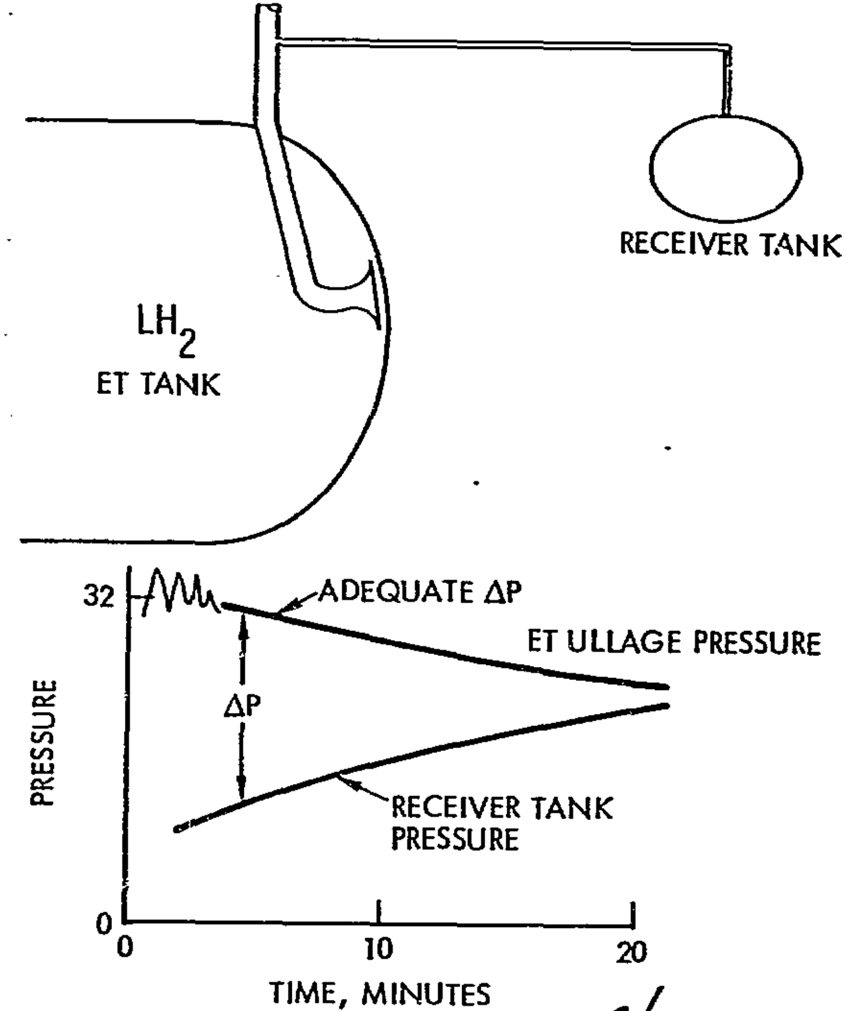
PROPELLANT TRANSFER PROCESS



PUMPED TRANSFER
REQUIRED



PRESSURIZED TRANSFER
THE WAY TO GO

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PAYLOAD IMPACTS

OPTION	ET IMPACT ZONE	NO. OF RCS THRUSTERS	THRUST (LB)	ULLAGE TIME (MINUTES)	ΔV MECO (FPS)	ΔV P/L (1) PER ΔMECO (LB)	ΔOMS PROPELLANT (LB)	RCS PROPELLANT FOR ULLAGE THRUST (LB) TOTAL	RCS PROPELLANT FOR ULLAGE THRUST (LB) CROSSFEED	ΔP/L NET (LB)
1	I	2	1740	5	-50	+1284	+474	2070	466	+ 344
2	I	1	870	5	-25	+ 642	+ 469	1035	- 569 (2)	+742
3	I	0	50+DRAG	20	-5	+128	+ 260	224	- 1380 (2)	+1248
4	II	1	870	20.3	0	0	- 2597	4306	2702	- 105
5	II	2	1740	11	0	0	-2564	4554	2950	- 386
6	II	2	1740	8	+30	-771	-2589	3312	1708	+110

(1) AN EARLY MECO CUTOFF PROVIDES AN INCREASE IN PAYLOAD AT THE RATE OF 25.7 LB PER FPS

(2) NEGATIVE NUMBER INDICATES LESS THAN FULL RCS PROPELLANT IS REQUIRED AND OFFLOADED PROPELLANT COULD BE CREDITED TO ADDITIONAL PAYLOAD.

NEGLIGIBLE PAYLOAD IMPACT

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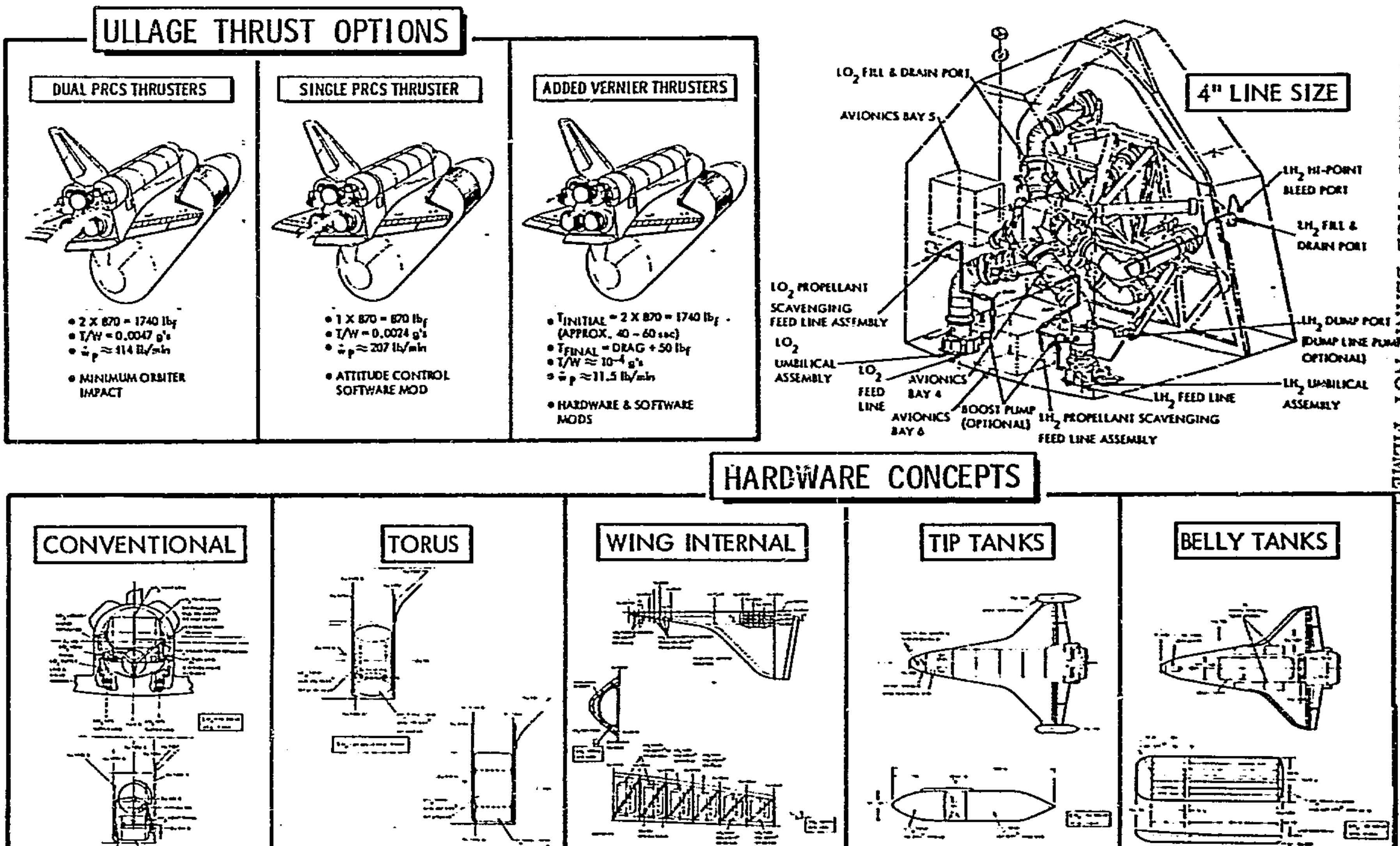
PRACTICAL SCAVENGING CONCEPTS



CREW AND SAFETY CONSIDERATIONS

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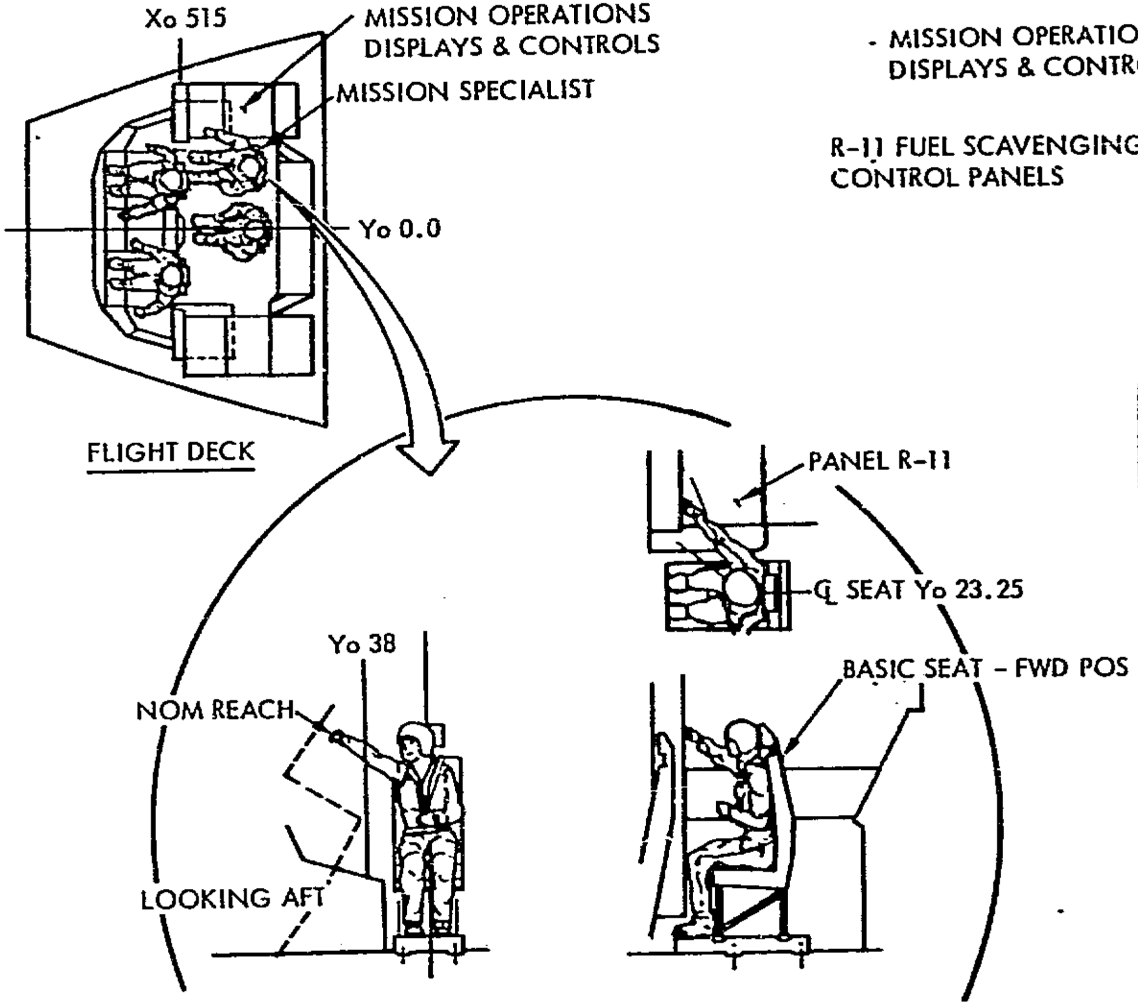
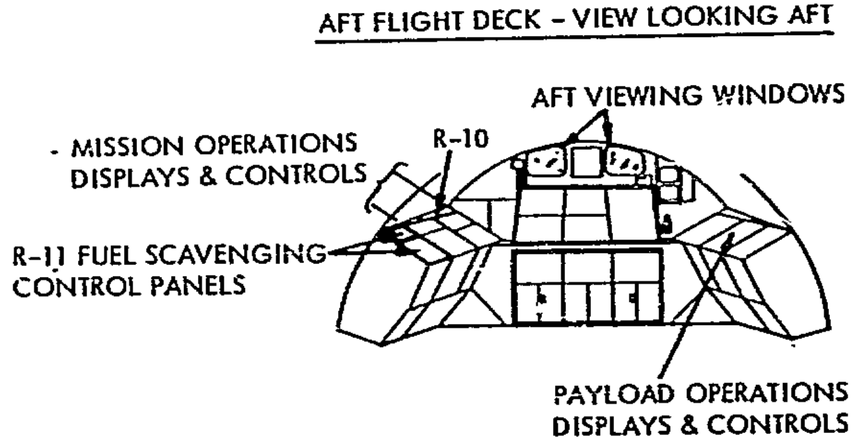
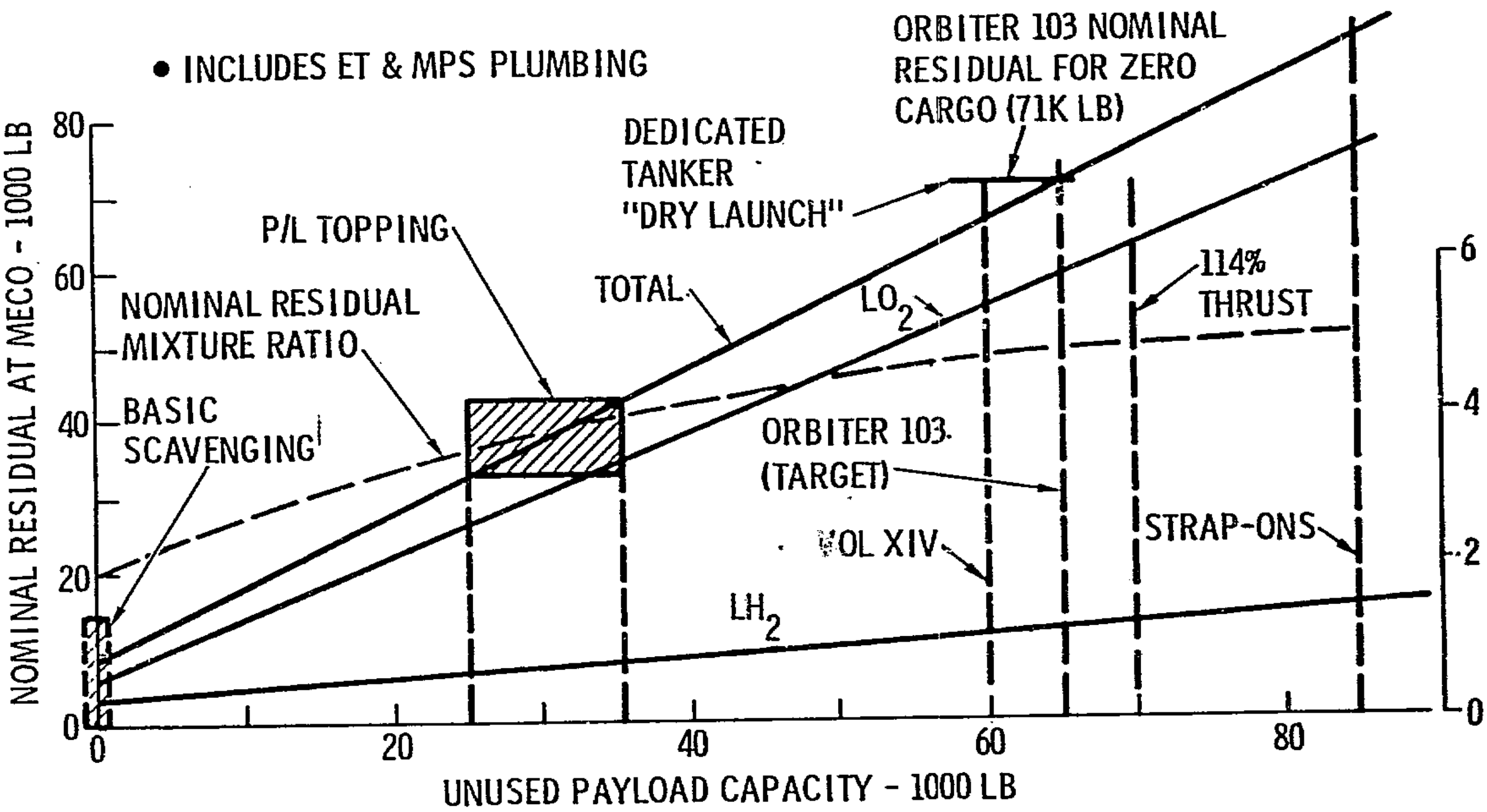




- PANEL SPACE IS AVAILABLE
- C&D'S WITHIN REACH
- OPERATIONS OCCUR AFTER MECO
- PLUMBING SIMILAR TO EXISTING RECIRCULATION SYSTEM
- DESIGN & QUALIFY TO MPS PLUMBING REQ
- ACCEPTABLE ET IMPACT ZONES ARE POSSIBLE
- ADEQUATE SAFETY CAN BE PROVIDED

NOMINAL PROPELLANT RESIDUALS AT MECO



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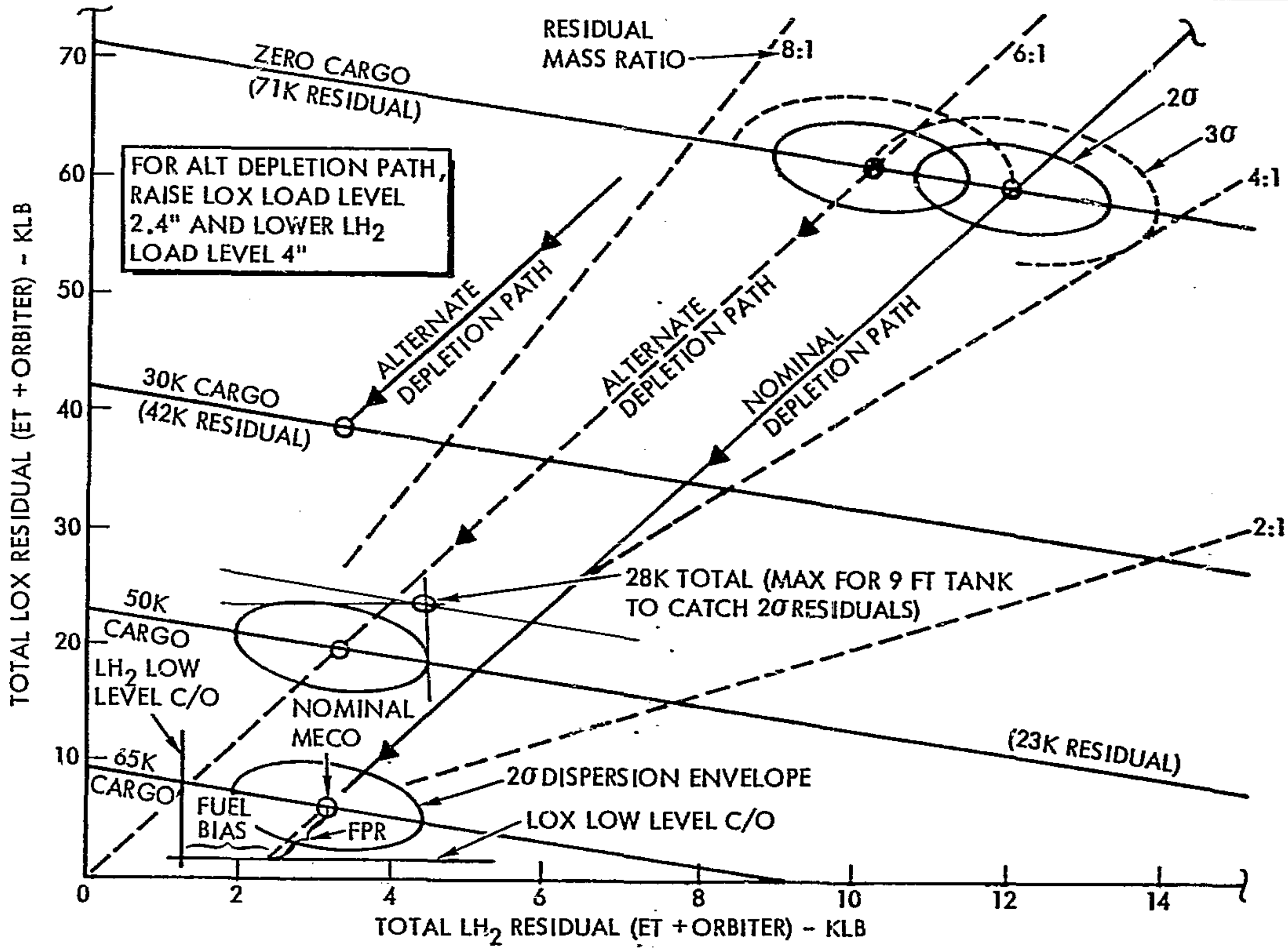
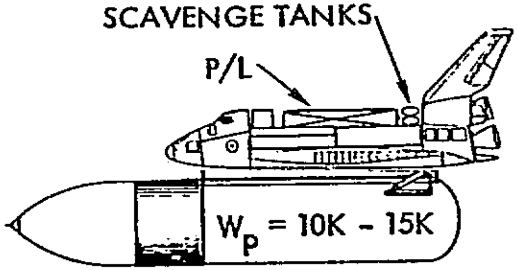
PRELIMINARY STATISTICAL DISPERSIONS OF RESIDUALS AT MECO



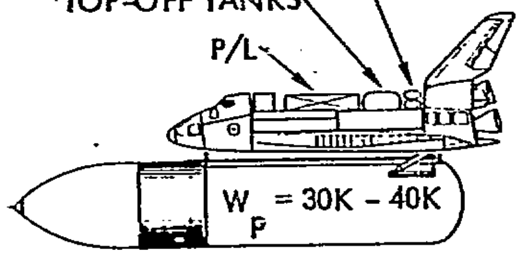
POSSIBLE SCAVENGING SCENARIOS

BASIC SCAVENGING



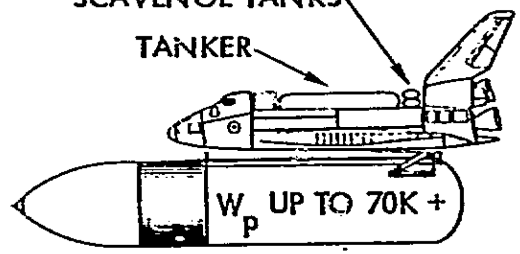
- LAUNCH WITH 65K P/L
- RECOVER STATISTICAL FPR
- SIZE SCAVENGE SYSTEM TO +3σ RESIDUALS
- OPTIONS CAN BE SIZED TO OTHER P/L WEIGHTS

P/L TOP-OFF



- LAUNCH WITH LESS THAN 65K HARD CARGO
- TOP-OFF TO 65K WITH PROPELLANT
- SIZE SCAVENGE SYSTEM TO +3σ RESIDUALS
- OPTION TO COMBINE SCAVENGE VOLUME INTO TOP-OFF TANKS
- OPTION TO LAUNCH "DRY"

DEDICATED TANKER



- LAUNCH WITH 65K PROPELLANT
- SIZE SCAVENGE SYSTEM TO +3σ RESIDUALS
- OPTION TO OVERSIZE TANKER TO INCLUDE SCAVENGE
- OPTION TO LAUNCH "DRY"

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IMPLICATIONS ON THE SOC SYSTEM

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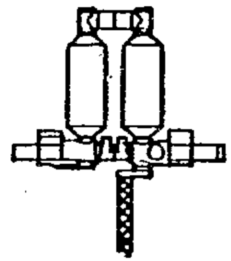
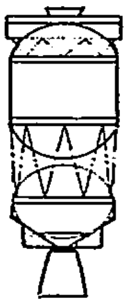
SOC



- CRYO STORAGE & HANDLING FACILITY
- "0-G" TRANSFER
- MASS VARIATIONS
- ADDED FRONTAL AREA
- ELECTRICAL POWER
- ORBITER INTERFACE
- OTV INTERFACE

OTV

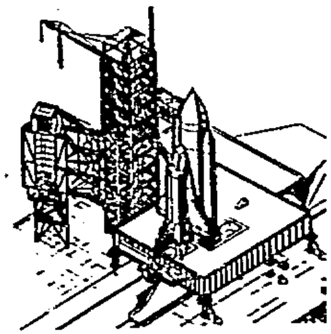


- SPACE BASED
- REUSABLE
- SIZED TO MISSION
- SOC REFUEL INTERFACE

ORBITER

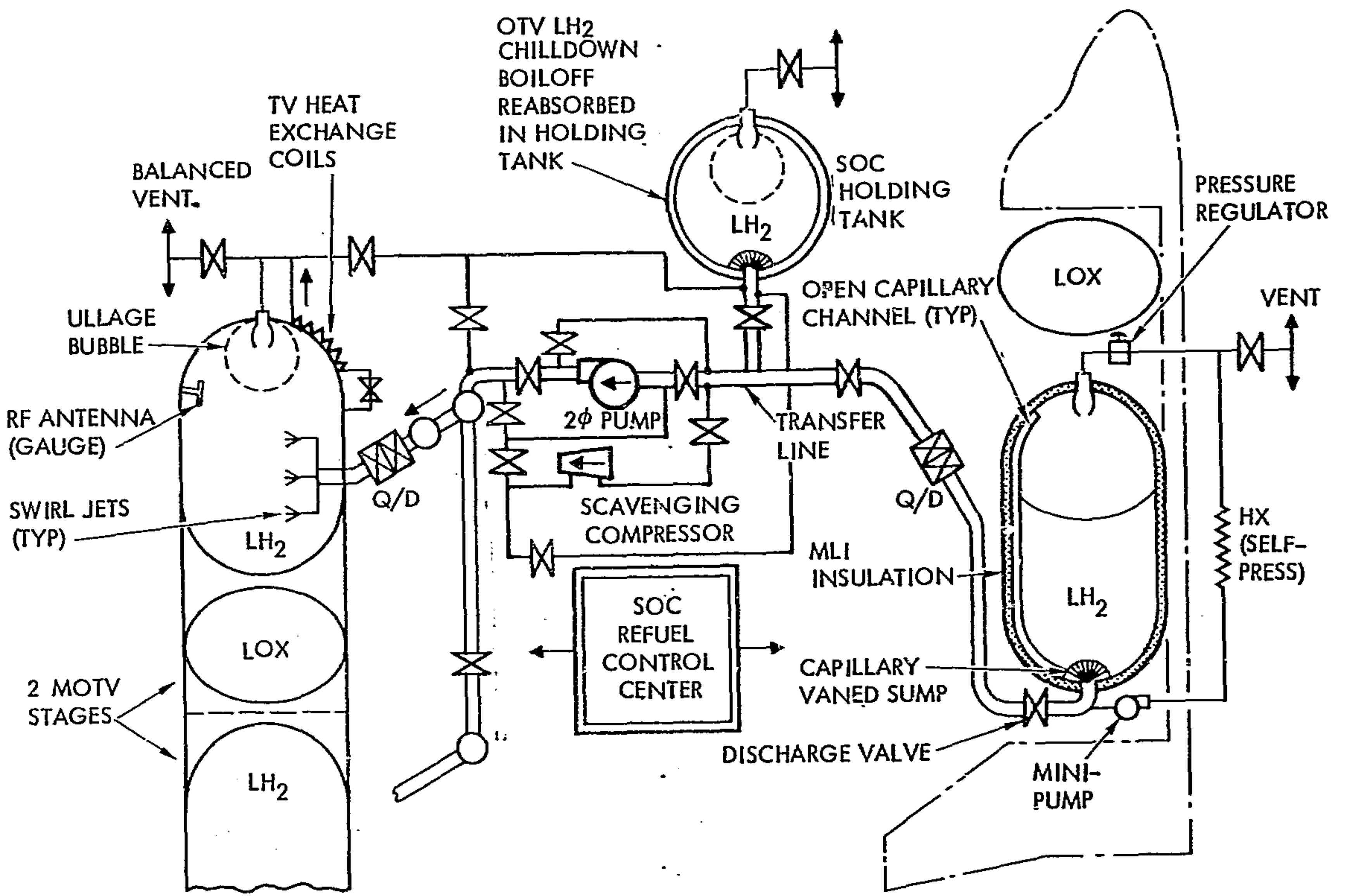
- HDWE MODS TANKS & EQUIP
- RCS
- SOFTWARE
- SOC INTERFACE

GROUND



- H_2 TANK CONDITION
- ET LOADING CONTROL
- DESERVICING OPS
- MANIFEST PLANNING

SOC CRYO - PROPELLANT HANDLING AND STORAGE FACILITY



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CRYO SYSTEM FUNCTIONAL REQUIREMENTS

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LONG TERM STORAGE ON SOC

- MASS VARIATIONS
- INCREMENTAL BUILDUP
- SLOSH EFFECTS
- INSULATION (PLUME CONTAMINATION)
- LIQUID-FREE, ZERO THRUST VENT
- REFRIGERATION AUGMENTATION

CRYO FLOW PROCESS & CONTROL

- 2 PHASE PUMPS
- 2-WAY TRANSFER
- TANK VAPOR SCAVENGING
- ACCURATE "O-G" GAGING
- REMOTE CRYO CONNECT/DISCONNECT

SERVICE ORBITER SUPPLY TANKS

- SCAVENGE VAPOR
- VENT
- REPRESSURIZE

UTILITIES SUPPORT

- ELECT POWER
- DATA MGMT
- ORBIT MAKEUP
- ATTITUDE STAB/CONT
- He REPRESS STORAGE

GROUND SYSTEM

- H_2 TANK CHILLDOWN
- ET LOADING CONTROL
- ORBITER TANK DESERVICING OPS
- MANIFEST PLANNING

SAFETY & HAZARD PROTECTION

- LEAK DETECTION
- MONITOR/ALARM CRYO STORAGE
- CRYO TANK RUPTURE (RCS ANTI SPIN-UP)

TECHNOLOGY ADVANCEMENTS FOR CRYO STORAGE/RESUPPLY

- ZERO-G LIQUID GAGING (RF, ACOUSTIC RESONANCE)
- REMOTE-ACTUATED, CRYO FLUID DISCONNECTS
- LIGHT WEIGHT CAPILLARY SYSTEM FOR DETANKING OTV's
- ADVANCED PASSIVE INSULATION FOR STORAGE (VAPOR-COOLED SHIELDS)
- LIQUID-FREE VENTING (THERMODYNAMIC VENTING OR SWIRL TECHNIQUES)
- 2 PHASE TRANSFER PUMP MOD & REQUAL
- VAPOR TURBOCOMPRESSOR MOD & REQUAL
- CRYO REFRIGERATOR (ADAPT MINI-HALO TURBO BRAYTON CONCEPT)
- 2 PHASE FLUID QUALITY METER

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STATUS OF PROPELLANT TRANSFER TECHNOLOGY

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LOW-G

- MULTIPLE RESTARTS OF S-IVB & CENTAUR DEMONSTRATED (ANALOGOUS TO ET SCAVENGING ACQUISITION) ET PROPELLANT SETTLING DEMO (WITH RCS) READILY ACCOMPLISHED

ZERO-G

- VIDEO RECORDING OF LH_2 FLUID PHENOMENA IN S-IVB, ON ORBIT
- MUCH DROP TOWER & KC-135 ZERO-G TESTING OF CAPILLARY PROPELLANT ACQUISITION SYSTEMS
- SHUTTLE RCS & OMS STORABLE PROPELLANT TANK FEED-OUT DEMONSTRATED IN FLIGHT (ZERO-G & ADVERSE - G's)
- NASA SPONSORING LH_2 TRANSFER EXPERIMENT ON SHUTTLE (OEX IN '83 - '84) TO EVALUATE CHILLDOWN & CAPILLARY SYSTEM PERFORMANCE

CONCLUSION

- MODERATE DEVELOPMENT EFFORT REQUIRED
- TECHNICAL RISK IS LOW

TASK 3.0 SUMMARY

- ET PROPELLANT SCAVENGING IS FEASIBLE & PRACTICAL
- BENEFITS ARE ENORMOUS
- PROPELLANT STORAGE IS REQUIRED
- SPACE BASED OTV MAXIMIZES BENEFITS
- MAJOR FUNCTIONAL IMPLICATIONS ON SOC ARE DEFINED
- TECHNOLOGY ADVANCEMENTS APPEAR NOMINAL

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EXECUTIVE SUMMARY

SHUTTLE FLEET UTILIZATION & PROGRAMMATICS

SOC ASSEMBLY OPERATIONS

FLIGHT SUPPORT FACILITY

SHUTTLE SYSTEM PROPELLANT SCAVENGING

CLOSING REMARKS

FUTURE TASKS

- CRYO PROPELLANT HANDLING & DELIVERY
  - PERFORM A ϕA DESIGN OF THE ORBITER SCAVENGING SYSTEM INSTALLATION
  - DEVELOP A SOC CRYO PROPELLANT STORAGE SYSTEM
  - DETERMINE THE GROUND FACILITIES & OPERATIONS REQUIRED TO SUPPORT ORBITER/E.T. SCAVENGING
  - DEFINE A STANDARDIZED CRYO PROPELLANT STORAGE TANK CONCEPT

- OTV CONCEPT
  - DEVELOP A SPACE BASED OTV CONCEPT
  - DEFINE STANDARD SERVICING INTERFACES/UMBILICALS

- RMS OPERATIONS
  - PERFORM A DYNAMIC ANALYSIS OF RMS OPERATIONS DURING SOC ASSEMBLY

- MODELS/POLICIES
  - DEFINE A SPACE DEBRIS MODEL
  - DEFINE A SOC COSTING/CHARGING POLICY
  - DEFINE A BASELINE SPACE PROGRAM MISSION MODEL